STUDIES ON SPORULATION AND PROPAGATION IN SELECTED AGAROPHYTES

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MARCH, 1985

CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON SPORULATION AND PROPAGATION OF SELECTED AGAROPHYTES" is the bonafide record of the work carried out by Kumari SHOBHA PRATAPRAO SHERE under my guidance and supervision and that no part thereof has been presented for any other Degree.

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DECLARATION

I hereby declare that this thesis entitled "STUDIES ON SPORULATION AND PROPAGATION IN SELECTED AGAROPHYTES" has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

Cochin-682 018
March, 1985.

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PREFACE

After passing M.Sc. in Botany with Palynology as a special subject, the candidate joined the Central Marine Fisheries Research Institute for the Ph.D. programme of the Centre of Advanced Studies in Mariculture in 1980. During the first semester she got familiarised with the various disciplines connected with mariculture such as basic science, finfish culture, mussel culture, shrimp culture, seaweed culture, environmental monitoring and connected field work and analytical techniques. During this period the candidate was assigned the work on sporulation and propagation in some agarophytes. After passing the qualifying examination with mariculture and algology as special subjects, the candidate moved over to the Regional Centre of CMFRI, Mandapam Camp for collecting field data and carry out the laboratory work.

During the stay at Mandapam the candidate had been visiting Kilakkarai, Thonithurai and Puthumadam fortnightly to collect field data on four species of agarophytes viz., Gelidiella acerosa (Forsskal) Feldmann et Hamel, Gracilaria corticata J. Agardh, G. edulis (Gmelin) Silva, and Hypnea musciformis (Wulfen) Lamouroux. In addition, the candidate

also visited the coral islands near Rameswaram Island in the Gulf of Mannar where there are luxuriant algal flora. Because of its unique position with the Gulf of Mannar having a typical oceanic environment and ecological conditions on one side and Palk strait with eutrophic conditions on the other side, and the changing pattern of the monsoon and winds make one area or the other at Mandapam always approachable for field work and sample collections.

The samples were regularly brought to the laboratory and sporulation studies under different environmental conditions were carried out in the laboratory for *in vitro* experiments.

The theme of the work is focussed on the spore output studies of some economic agar and carragheenan producing red algal species of Gelidiales and Gigartinales of Floridiophycae; *Gelidiella acerosa* (Forsskal) Fieldmann et Hamel, *Gracilaria corticata* J. Agardh., *Gracilaria edulis* (Gmel) Silva; and *Hypnea musciformis* (Wulfen) Lamouroux. The study was carried out for two years from October 1981 to October 1983. Data were collected on the seasonal and diurnal aspects of spore liberation of the four red algae to know the spore liberation of the four red algae and to know the spore production potential of the fertile fronds during different months of the year.

Experiments were also conducted in the laboratory to understand the effects of different environmental factors such as desiccation, salinity, temperature, light-intensity and photoperiod on spore shedding. During these experiments some information on spore germination has also been collected.

ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to Dr. P.V. Ramachandran Nair, Scientist S - 3 and Head, Fishery Environment and Management Division, Central Marine Fisheries Research Institute for encouragement and guidance given during the research work, which enabled this programme of work to materialise. I wish to express my most sincere gratitude to Dr. E.G. Silas, Sub-Project Coordinator and Director, Central Marine Fisheries Research Institute, Cochin-18 whose suggestions and directions given at different stages of the research study were equally beneficial. The candidate extends her heart-felt thanks to Dr. E.G. Silas for the same and for providing various facilit[illegible] of the C.M.F.R. Institute, Cochin and the Regional Station at Mandapam Camp till the completion of the thesis.

I offer my sincere thanks to Shri S. Mahadevan, Officer-in-Charge, Mandapam Camp and to the then Joint-Director, Dr. P.S.B.R. James for providing necessary help and various facilities during the research work at Mandapam Camp. To Dr. N. Kaliaperumal, Scientist S - 2, who has rendered advice, guidance, help and most of the supervision at various stages of the research work during the research study at Mandapam Camp, I offer my most sincere gratitude. I also offer my sincere thanks to Dr. V.S.K. Chennubhotla,

Scientist S - 2, for providing necessary help and guidance and my thanks are also due to Shri Krishnapillai, Shri S.Kalimuthu, Shri J.R. Ramalingam, Shri S. Selvaraj, Shri M. Najmuddin and other scientists and the staff of Mandapam Regional Centre for extending help in various ways during the research work.

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CHAPTER - 1

INTRODUCTION :

The decade of 1970s heralded a major research effort into mariculture of economically important red and brown sea-weeds, particularly the agarophytes and alginophytes. The limited and declining natural populations, lack of synthetic substitutes for the phycocolloids with their upwardly spiralling costs have emphasised the need for more research in this area. Now, algal mariculture has become technically and scientifically more feasible.

The marine red algal species (agarophytes) of Florideophyceae, (Rhodophyta) especially belonging to the orders Gelidiales and Gigartinales are used for the manufacture of agar-agar, carrageenan and other phycocolloids in many countries. "Agarophyte" is a term applied to those sea-weeds producing amorphous gelatinous substance referred as 'agar'. In India Gelidiella acerosa and Gracilaria edulis are used as raw material for the manufacture of agar-agar by the sea-weed industries. Apart from this, several genera of the order Gelidiales such as Acanthopeltis, Gelidiella, Gelidium, Pterocladia and Suhria and those of the order Gigartinales like Agardhiella, Chondrus, Eucheuma, Gigartina, Gracilaria, Gymnogongrus, Hypnea and Sarcodia are consumed as food either as raw or in processed form in different

countries particularly in the Indo-Pacific region. This obvious use of sea-weed for food has reached its peak in Japan where different species are harvested for this purpose. In Wales and Ireland laver (Porphyra umbilicais) is a traditional delicacy. In many countries seaweed biomass is used as animal fodder, fertilizer or as an energy source to produce methane gas. Seaweed extracts and composts are applied to crops as a nutrient source and soil conditioner. (Subba Rao, 1965; Levring et al., 1969; Santelices, 1974; Michanek, 1975 and Chapman and Chapman, 1980).

Many genera and species of the orders Gelidiales and Gigartinales are widely distributed in temperate and tropical to sub-tropical waters of the world. In India 6 species of Gelidiella (Sreenivasa Rao, 1970 and Sreenivasa Rao and Trivedi, 1974), 17 species and 2 varieties of Gracilaria (Umamaheswara Rao, 1972 a) and 9 species of Hypnea (Untawale et al., 1983) have been reported. Many of these species form an important component of the seaweed vegetation at various localities along the Indian shores. Along the coasts of Mandapam Gelidiella acerosa, Gracilaria arcuata var. arcuata, G. arcuata var. attenuata, G. canaliculata, G. corticata var. corticata, G. corticata var. cylindrica, G. cylindrica, G. disticha, G. edulis, G. follifera, G. indica, G. mannarensis, G. millardetii, G. obtusa, G. textorii,

G. verrucosa, Hypnea musciformis, H. pannosa, H. spinella and H. valentiae have been recorded by some workers (Umamaheswara Rao, 1969 and 1972 and Rama Rao and Subbaramaiah, 1980).

A vast amount of literature is available on the morphology, taxonomy, growth, reproduction and phycocolloid content of some economic seaweeds e.g., Gelidiella acerosa of the order Gelidiales and various Gracilaria and Hypnea species of the Gigartinales order (Floridiophyceae, Rodhophyta) by Fritsch (1945) Umamaheswara Rao, (1969 and 1972), Rama Rao and Subbaramaiah, (1980), Rao, (1970), Rao and Krishnamurthy (1968), K. Rama Rao (1970 - 1982). But the informations that are available on spore producing capacity of the algae are scanty particularly with reference to the effect of environmental factors on spore shedding and the germination of spores. In order to assess the mariculture potential of these species by spore method, sporulation studies on the same were undertaken on Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis growing along the Mandapam coast.

Studies on spore phenomena have been initiated in some economic algae such as Gelidiella, Gelidium, Porphyra, Gracilaria and Hypnea of Rhodophyta and Dictyota, Turbinaria, Padina species of Phaeophyta and in Ulva species of Chlorophyta by Rao, (1971 a b), Tanaka, (1941), Mshigeni, (1976), Suto, (1950), Yinam Ngan and Price, (1983). Detailed knowledge on sporulation is not available as regards the other members of Gelidiales and Gigartinales occuring along the Indian coasts.

During the present work, carried out for a period of 2 years from October 1981 to September 1983, data have been collected on the fruiting behaviour and experiments were conducted at room temperature on the daily and seasonal changes in the shedding of tetraspores of Gelidiella acerosa and tetraspores and carpospores of Gracilaria corticata, G. edulis and Hypnea musciformis and also periodicity in the daily liberation of spores in these four red algae. Influence of important environmental factors such as desiccation, salinity, light and temperature on the spore output have been studied in detail.

Data have also been collected on germination of spores of four red algae. Informations on the hydrological conditions of the inshore waters in the vicinity of Mandapam such as surface sea-water temperature, pH, salinity and dissolved oxygen were also collected. Results obtained on the above aspects are presented and discussed in this thesis.

CHAPTER - 2

REVIEW OF LITERATURE

The red algal members of Florideophyceae (Rhydophyta) especially belonging to the orders Gelidiales and Gigartinales occuring in various regions of the world have been studied for the past four decades in view of their commercial value as a sources of agar-agar and human food. These investigations carried out on different species of Gelidium and Pterocladia (Santelices, 1974), Gracilaria (Hoyle, 1975) and Hypnea (Mshigeni, 1976 a, b, d and 1977 and 1978) and Mshigeni and Lorri (1977) provide pertinent information to our knowledge on their taxonomy, biology and economic importance.

Studies have been conducted in India on some important members of the order Gelidiales and Gigartinales. Among the order Gelidiales, studies were carried out on the ecology, commercial utilisation and cultivation of Gelidiella acerosa, by Sreenivasa Rao, (1969, 1971 a, b, c, 1974 and 1976); Umamaheswara Rao, (1973 a and 1974 a); Sreenivasa Rao and Trivedi, (1974); Subbaramaiah et al., (1974 and 1975); Bhanderi, (1974); Krishnamurthy et al., (1975); Subbaramaiah et al., (1975): Thomas et al.,(1975 a and b); Rama Rao et al.,(1976); Chennubhotla et al., (1977a, b and 1979); Rama Rao and Subbaramaiah,(1977 and 1979); Joshi and Chauhan, (1979); Subba Rao, (1979);

Mairh et al., (1979 a, b); Patel et al.,(1979 and 1980) other species of Gelidiella (Subba Rao, et al., (1977) and Untawale, et al., (1977), Gelidium Pussilum and Pterocladia heteroplatos by (Umamaheswara Rao and Sreeramulu, (1964) Mairh and Sreenivasa Rao, (1978); Kaliaperumal, (1979); Kaliaperumal and Umamaheswara Rao, (1981); and Umamaheswara Rao and Kaliaperumal, (1983).

Among the members of the order Gigartinales, investigations on taxonomy, morphology and anatomy were carried out in certain species of Gracilaria by Ahmed, (1966); Oza and Krishnamurthy, (1967 and 1968); Krishnamurthy et al., (1969); Raju and Thomas, (1971); Umamaheswara Rao, (1972 b, 1973 b, c, 1974 b and 1976); Rama Rao and Thomas, (1974); Oza, (1975, 1976, 1978 and 1979); Subbarangaiah et al., (1975); Thomas and Krishnamurthy, (1976); Thomas. (1977); Rama Rao, (1977 a); Mohan Joseph and Krishnamurthy, (1977); Chennubhotla et al.,(1978 and 1979); Subba Rangaiah, (1978) and Umamaheswara Rao and Subba Rangaiah, (1980) and Hypnea by Rama Rao (1970, 1972, 1976, 1977 a, b, 1979, and 1982); Rama Rao and Krishnamurthy, (1968 and 1978); Subba Rangaiah (1978); Rama Rao and Subbaramaiah, (1980); Umamaheswara Rao and Subba Rangaiah, (1980); Solimabi et al., (1980); Rama Rao et al (1983).

2.1 SEASONAL GROWTH BEHAVIOUR

The plants of Gelidiella acerosa in the Palk Bay near Rameswaram and in the Gulf of Mannar near Pudumadam have been observed throughout the year by Umamaheswara Rao, (1973 a) and these plants attained maximum size in two seasons with a half yearly growth cycle. The main growth season with maximum number of large sized fronds was found between December and April on the Palk Bay side and between July and August on the Gulf of Mannar side by Umamaheswara Rao, (1973 a). Gelidiella acerosa occurring on the reef at Kilakkarai reached maximum growth in November, as measured by the length, bushiness and the number of branches of plants (Thomas et al., 1975 a) and the plants showed 2 peak growths for the same period, one in July and another in November, as measured by wet and dry method (Thomas et al., 1975 b). The peak values in monthly growth rates in length and percentage cover of Gelidiella acerosa growing at Ervadi near Kilakkarai were recorded during summer months May to July. Higher growth rate in cover was also observed during winter months November to December (Rama Rao and Subbaramaiah, 1979). Subba Rao, (1979) observed that the mean monthly growth rates of the plants taken individually or as in population were maximum in January at Ervadi and in February at Rameswaram. Chennubhotla

et al., (1979) also observed the vegetation of Gelidiella acerosa occurring throughout the year at Pudumadam, Kilakkarai and Krusadai Island.

The seasonal growth behaviour of Gracilaria corticata growing in the Gulf of Mannar side near Mandapam was studied by Umamaheswara Rao (1972 b). He stated that these plants occurred throughout the year with its peak growth from June to September and another small peak in November or December. Similarly Chennubhotla et al., (1979) reported the occurrence of Gracilaria corticata in all the months of the year from Pudumadam.

Population of Gracilaria edulis in the Palk Bay near Rameswaram was also observed throughout the year by Umamaheswara Rao (1973 b). Increase in mean length was observed by him from November or December and a large number of plants reached their maximum height during the period January to April, after which there was a decline in the mean length particularly during May and June. This reduction in the height seemed to be due to the breakage or removal of fully grown and old fronds (defoliation) and also by the development of fresh plants in the population. Again another small or secondary peak in growth was found in August and September with increase in height from July. During October/November there was

a considerable decrease in the average length of the plants. Similarly Chennubhotla et al., (1979) also recorded the vegetation of Gracilaria edulis throughout the year at Rameswaram and Krusadai Island.

2.2 Fruiting Behaviour :

Tetrasporophytes were observed only for some months in the population of Gelidiella acerosa growing at Veraval by Sreenivasa Rao, (1974) and at Rameswaram by Umamaheswara Rao (1973 a) and Rama Rao et al., (1976).

In Gracilaria corticata growing at Veraval, tetrasporic phase occurred almost throughout the year while sexual phase was seasonal occurring from September to February (Oza, 1979). Tetrasporic and cystocarpic plants of Gracilaria edulis occurred through the year in the Gulf of Mannar side at Mandapam (Umamaheswara Rao, 1976) and Visakhapatnam coast (Subba Rangaiah, 1978). In Gracilaria edulis growing at Rameswaram in the Palk Bay tetrasporophytes occurred in all the months except in October or November. Antheridial and cystocarpic plants were seen only in the month of January and only one or two plants were observed in the samples examined (Umamaheswara Rao, 1973 b).

2.3 SPORE PRODUCTION POTENTIAL IN ALGA

The spore production potential has been investigated in a few economic seaweeds. Suto (1950) developed a method for counting the number of spores produced by seaweeds over a given period of time. In this method, a known size of a sporulating thallus was collected from the field, brought to the laboratory, and placed in a container of seawater with a glass plate at the bottom. The spores liberated fall on to the glass plate. The plate containing the spores is brought under the microscope and the spores are counted at hourly intervals for 12 hours. The mean value of the count is then used for estimating the rate of spore liberation and the total number of spores which a mature thallus can produce. This method involves the counting by rows and has been called (Katada 1955) the 'obi' method.

Suto (1950) in his counts on the spore production potential in Gelidium amansii found that 1.0 g of a fertile frond of this species produced about 10^4 to 10^5 spores per day. Oza and Krishnamurthy (1967) using the same method (with slight modifications) found that in Gracilaria verrucosa a single mature cystocarpic plant produced up to 1.97×10^4 carpospores per day in December, the season of maximum spore shedding. Similarly, Rao (1971 a) found that an average sized tetrasporic thallus of Gelidiella acerosa

produced 2 x 10^4 spores per season (i.e. October - November).

Neushul (1972) developed a different method in estimating the spore-production potential in Macrocystis pyrifera, by measuring the number of sporangia per square millimeter of the sporangial area and multiplying this by 32, the number of spores in each sporangium. He estimated 3.5 x 10^5 spores per mm^2 of sporangial area on each side of sporophyll (Anderson and North 1966).

In Saccorhiza dermatodea, individual sporangia were found to contain 128 zoospores (Norton 1972), in Gracilaria verrucosa about 200 to 2000 carpospores can be obtained (Kin 1970) from a single cystocarp, while in Gelidium robustum 65 to 430 carpospores may be obtained (Guzman - del Proo et. al., 1972) from a single cystocarp and the total number of spores produced by a mature thallus may be 34,000 to nearly 300,000 carpospores. In most other seaweeds like Gracilaria corticata, G. edulis and Hypnea musciformis occurring at Mandapam coast, this kind of investigations has not been conducted.

The reproductive capacity of the two species of Hypnea specially H. Musciformis at Veraval, West coast of India AND H. valentiae at Pamban and Krusadai Island, East coast of India was studied over different seasons by Rama

Rao (1977 b). The tetrasporophytes in Hypnea musciformis occurred throughout the year with no distinct peak while cystocarpic plants occured only in October each year. The tetrasporic plants in Hypnea valentiae also occurred in all months at Pamban and Krusadai Island while the cystocarpic plants occurred for 11 months at Pamban and for 7 months in a year at Krusadai Island. Maximum frequency of tetrasporophytes and carposporophytic plants of Hypnea valentiae at Pamban and Krusadai Island occurred in February and June/July respectively. Male plants were not observed both in Hypnea musciformis and H. valentiae. At Visakhapatnam coast tetrasporophytes and carposporophytes in the population of Hypnea musciformis occurred in all the months of the year (Subba Rangaiah, 1978).

2.4 SPORE SHEDDING :

Information available on spore shedding in natural and in different environmental conditions influencing spore shedding is very little on red algal genera. Japanese workers paid more attention to this aspect and collected data on Gelidium, Porphyra and other economically important seaweeds. The spore output estimated by Suto (1950 a and b) for the fronds of Gelidium varied from 1,00,000 to 10,00,000 spores/g. fresh wt./day and the spore shedding was found

chiefly for one day. Boney (1960) estimated spore output in Antithamnion plumula for a number of days with more than 50 % spore release in the first 24 hrs, about 20 % on the second day and 16 % after 3 days.

Studies have been conducted on sporulation of some red algae growing at Mandapam area and other localities of Indian coast. Gelidium pusillum and Pterocladia heteroplatos at Visakhapatnam coast were studied by Kaliaperumal(1979). Gracilaria corticata from Mandapam region was studied by Umamaheswara Rao (1976) and Mohan Joseph and Krishnamurthy (1977). Rama Rao and Thomas (1974) collected Gracilaria edulis from Krusadai Island near Mandapam and studied carpospore output. Krishnamurthy (1967) reported tetraspore output in Gracilaria millardetii. Oza and Krishnamurthy (1968) observed liberation of carpospores per plant in Gracilaria verrucosa growing at Kuda near Bhavnagar in Gujarat. The tetraspore and carpospore shedding in Hypnea valentiae from Mandapam was studied by Rama Rao (1979), Subba Rangaiah (1978) collected data on tetraspore and carpospore output in four members of Gigartinales order namely Gracilaria corticata, G. textorii, Gracilariopsis sjoestedtii and Hypnea musciformis growing at Visakhapatnam coast. Shedding of tetraspores from stichidia in

Gelidiopsis variabilis was observed for 3-4 days at Visakhapatnam coast by Kaliaperumal and Umamaheswara Rao, (1982).

2.5 SEASONAL CHANGES IN SPORE OUTPUT :

Seaweeds vary tremendously in the timing of their spore production. In some of the warm eastern shoreline of South Africa (Isaac and Hewitt, 1953) or the tropical regions such as India (Rao 1970) where the growth of Hypnea, occurs throughout the year, tetrasporangia are borne on the thalli throughout the year. Dictyota dichotoma and Centroceros clavulatum in India also produce spores (Umamaheswara Rao and Sreeramulu 1970) throughout the year.

In Gracilaria verrucosa, spore maturation was observed only (Oza and Krishnamurthy 1967, Ogata 1972) at certain periods of the year. In this alga the cystocarps were found in September or October in India and the peak spore production was attained in December or January. Tetrasporic thalli in contrast was seen only from March to September. In Gelidiella acerosa, there were observed (Rao, 1971 a) two spore-shedding seasons a year in India: (from April to May and from October to November), each spore shedding season lasting 25 to 30 days. In Baja California, Gelidium robustum has its peak for spore production during August

and September (Guzman - del - Proo et al., 1972), the total number of spores released gradually decrease towards January and February, coinciding with winter. In many algae, the season of fertility is related to the geographical location where the alga grows, and this may be correlated with temperature or day length.

Seasonal changes in spore output in some seaweeds have been reported by few workers. Sreenivasa Rao (1971 a and 1974) studied seasonal variation in tetraspore output in Gelidiella acerosa growing in the tide pools at Veraval. Gelidiella acerosa from Pudumadam was recorded by Umamaheswara Rao (1974). Kaliaperumal, (1979) collected data on the seasonal spore shedding in Gelidium pusillum and Pterocladia heteroplatos. Data on seasonal changes in tetraspore and carpospore output of Gracilaria corticata growing at Mandapam were observed by Umamaheswara Rao (1976) and Mohan Joseph and Krishnamurthy (1977). The seasonal change in tetraspore and carpospore output in Gracilaria corticata and Hypnea musciformis growing at Visakhapatnam coast was also observed by Subba Rangaiah, (1978). Oza, (1979) conducted laboratory experiments in Gracilaria corticata occurring at Veraval coast. He observed two peak periods of sporulation. Studies on the

seasonal rhythm in the shedding of tetraspores and carpospores in Hypnea valentiae from Mandapam were carried out by Rama Rao (1979). Maximum number of tetraspores was observed in February and carpospores in October.

The spore shedding in Gracilaria edulis growing at Rameshwaram was reported by Rama Rao and Thomas, (1974). He stated that the total spore output per plant showed peak values in July and August and gradual decrease by January. He further stated that higher values of spore output were seen again in February-March while in April-May a total lack of spores was observed. The spore shedding in Gracilaria verrucosa was further observed by Jones (1959 a) and Oza and Krishnamurthy, (1968) and in Gelidiopsis variabilis by Kaliaperumal and Umamaheswara Rao, (1982).

2.6 DIURNAL PERIODICITY IN SPORE SHEDDING :

Diurnal periodicity in spore liberation was observed in some members of the order **Gelidiales** and other red algae by few investigators. Suto (1950 b) and Katada et al., (1953) observed diurnal shedding of spores in Gelidium amansii daily in the afternoon. Fukuhara (1957) conducted diurnal experiments in Iridophycus cornucopiae and diurnal variation in shedding of spores was scarcely recognised. Matsui (1969) observed diurnal periodicity in the liberation of tetraspores and carpospores in Gloiopeltis tenax and in Gloiopeltis furcata. In the former maximum release of spores was noticed from evening to midnight and in the latter in the early morning. Umamaheswara Rao (1974 a) reported diurnal periodicity in the liberation of tetraspores in Gelidiella acerosa and in Gracilaria corticata (1976). Diurnal periodicity studies in the liberation of spores was also observed in Gelidium pusillum, Gelidiopsis variabilis and in Pterocladia heteroplatos by Kaliaperumal, (1979). A definite diurnal periodicity in the shedding of carpospores in Hypnea valentiae was reported by Rama Rao, (1979).

Recently Ngan and Price (1983) collected data on the diurnal periodicity of carpospores and tetraspores discharge in 14 red algal taxa growing in the vicinity of Townsville region, Queensland, Australia under a variety of laboratory conditions. Experiments were conducted at hourly or bi-hourly intervals over periods of 24 hours or in some cases 48 hours.

Differences in the time of peak shedding between tetraspores and carpospores was observed by some workers. Katada et al., (1953) in Gelidium amansii, Subba Rangaiah (1978) in Hypnea musciformis, Matsui (1969) in Gloiopeltis tenax and Gloiopeltis furcata; Umamaheswara Rao, (1976) and Subba Rangaiah, (1978) in Gracilaria corticata, in Gracilaria textorii and Gracilariopsis sjoestedtii by Subba Rangaiah (1978) and in Gelidium pusillum and Pterocladia heteroplatos by Kaliaperumal, (1979).

Seasonal variations in the diurnal periodicity of spore output were investigated by Katada et al., (1953) in Gelidium amansii. Similarly in Gelidium pusillum and Gelidiopsis variabilis seasonal changes in the diurnal periodicity of tetraspores was observed by Kaliaperumal(1979). In Gracilaria corticata, G. textorii, Gracilariopsis sjoestedtii and Hypnea musciformis the diurnal periodicity

of tetraspores and carpospores was reported by Subba Rangaiah, (1978). He observed that the diurnal periodicity of tetraspores did not vary in different months or seasons of the year.

2.7 EFFECTS OF ENVIRONMENTAL FACTORS ON SPORE SHEDDING : Effects of environmental factors like desiccation, salinity, light (intensity and photoperiod) and temperature on spore shedding have been further observed by some workers.

Since exposure to air and desiccation of plants caused by tidal action influence spore production (Suto, 1950 a) experiments were carried out by Katada (1955), Matsui (1969) and others, to study its effect. Katada (1955) reported that desiccation in the shade has no inducing effect upon the shedding of tetraspores in Gelidium amansii and in these experiments the time of shedding was extended within about half-a-day. On the contrary, Matsui (1969) reported accelerating effect in Gloiopeltis species.

Sreenivasa Rao, (1971 a) further reported that drying of tetrasporic plants in shade had no effect on spore output in Gelidiella acerosa. (Umamaheswara Rao, (1976), (in Gracilaria corticata) stated that tetraspore output decreased markedly in thalli exposed for one hour and there was no spore shedding with further increase of exposure to air.

While carpospores were not at all liberated from cystocarps during one hour exposure at room temperature. Recently Subba Rangaiah, 1978 and Umamaheswara Rao and Subba Rangaiah (1980) observed the effect of exposure to air of the tetrasporic thalli in Gracilaria corticata, Gracilaria textorri, Gracilariopsis sjoestedtii and Hypnea musciformis. The tetraspore output decreased in all plants with increase in the duration of exposure of the fronds and maximum spore release was observed under continuously submerged conditions. Recently Umamaheswara Rao and Kaliaperumal, (1983) studied exposure to air of tetrasporic fronds of Pterocladia heteroplatos, Gelidium pusillum and Gelidiopsis variabilis growing at Visakhapatnam coast. They observed maximum spores in submerged conditions. Umamaheswara Rao and Sanjeeva Reddy (1982) studied tetraspore shedding of the tetrasporic fronds in Dictyota dichotoma with maximum spore output in submerged conditions.

Yamasaki et al., (1957) studied the influence of sea water of various concentrations on the growth, formation of sporangia and liberation of spores from the conchocelis phase of Porphyra tenera. He found more number of spores in 28.19 ‰S whereas Matsui (1969) found that tetraspore liberation was not significantly influenced in salinities

between 17 %o and 52 %o in Gloiopeltis tenax and Gloiopeltis furcata. Monospore release was found in Acrochaetium endophyticum by White and Boney (1969) in the media of 19.2 %o - 49 %oS. Normal production of zoospores or gametes was found in Ulva fasciata by Mohsen et al., (1972) in the salinity range between 20 and 35 %o. Higher salinities from 35 %o to 45 %oS enhanced both the formation of swarmers and their discharge.

The spore output experiments in different salinities ranging from 10 - 60 %o were conducted by Subba Rangaiah et al., (1975), Subba Rangaiah (1978) and Umamaheswara Rao and Subba Rangaiah (1980) in which the optimum range observed for peak shedding of spores was 30 - 40 %o in Gracilaria corticata, G. textorii and Gracilariopsis sjoestedtii and in Hypnea musciformis maximum spores were obtained at 20 - 30 %o. Umamaheswara Rao and Kaliaperumal (1983) also conducted spore output experiments with tetrasporic thalli of Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis in different salinities ranging from 0 %o to 70 %o. In Gelidium pusillum and Pterocladia heteroplatos spore shedding was found at 10 %o - 60 %o and peak discharge at 30 %o salinity was obtained. In Dictyota dichotoma (Umamaheswara Rao and Sanjeeva Reddy (1982) maximum spore shedding was observed at 30 %o Salinity.

The effect of light intensity on spore shedding has been studied by some workers. White and Boney (1969) studied the production of monospores in Acrochaetium endophyticum. Massive spore output over long periods was seen in the light intensity range of 50 - 110 lumens/sq.ft.(538-1184 lux) in Monostroma by Ohno (1972). The effect of light intensity was further studied in Monostroma nitidum by Ohno and Nozawa, (1972), in the tetraspore shedding of Gracilaria corticata, Gracilaria textorii and Gracilariopsis sjoestedtii by Subba Rangaiah (1978) and Umamaheswara Rao and Subba Rangaiah (1980). In Gracilaria corticata, G. textorii and Gracilariopsis sjoestedtii maximum release of tetraspores were obtained in complete darkness, but in Hypnea musciformis spore output was higher at 750 ± 50 lux light intensity than in total darkness. Umamaheswara Rao and Kaliaperumal (1983) found peak liberation of tetraspores in Gelidium pusillum, Pterocladia heteroplatos, and Gelidiopsis variabilis at 500 lux.

The effect of day length on sporogenesis has been reviewed by Dixon and Richardson (1970) in Bangia fuscopurpurea. In this the conchocelis phase produced monosporangia only in short day photoperiods. Iwasaki, (1961) observed monospore formation and release of fertile monospores in

Porphyra tenera, induced by short day conditions. Work on photoperiod induction and liberation of monospores from the conchocelis phase in 5 species of Porphyra was observed by Kurogi and Suto (1962): Porphyra tenera, P. kuniedai, P. yezoensis, P. pseudolinearis and P. angusta. Liberation of monospores were also observed in short day conditions. Kurogi and Suto (1967) observed more liberation of monospores in Porphyra umbilicalis under long day conditions. In Acrochaetium endophyticum plants kept under long day conditions produced large number of monospores at all light intensities ranging from 30 - 500 lumens per sq.ft. (323 - 5382 lux). Ohno (1972) studied gamete liberation in Monostroma and found that long day treatment produced faster gamete liberation than short day treatment. Umamaheswara Rao (1974 a) observed maximum shedding of tetraspores at 16 + $\bar{8}$ LD cycle in Gelidiella acerosa. Liberation of tetraspores and carpospores in Gracilaria corticata was observed by Umamaheswara Rao (1976). He reported maximum tetraspore shedding in 0 + $\bar{24}$ LD cycle and carpospore output in 4 + $\bar{20}$ LD cycle. Similarly maximum release of tetraspores was observed by Subba Rangaiah (1978) and Umamaheswara Rao and Subba Rangaiah (1980) in Gracilaria corticata, Gracilaria textorii, Gracilariopsis sjoestedtii and Hypnea musciformis at 0+$\bar{24}$ LD

cycle, and the spore shedding decreased with increase in the duration of photoperiod. Recently Umamaheswara Rao and Kaliaperumal (1983) studied the combined effects of light and its day length on the shedding of tetraspores in Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis. Maximum spore output was obtained at light intensity of 500 lux and photoperiod of 16 : 8 and 24 : 0 LD cycles.

The relation between sporulation in seaweeds and temperature of seawater was studied by Suto (1950 a and b). According to Suto (195C a) spore shedding in seaweeds takes place when the seawater temperature has reached an optimum level for each species. He observed that spore liberation in Gelidium amansii takes place in the afternoon. Katada (1955) supported Suto's observation, also working on Gelidiales for Gelidium amansii. He stated that shedding time of tetraspores and carpospores varied according to the temperature of the seawater in the field. Fukuhara (1957) conducted experiments with Iridophycus cornucopiae. Kurogi and Akiyama (1966) examined the effect of water temperature on the liberation of monospores on 6 species of Porphyra, namely P. tenera, P. kuniedai, P. yezoensis, P. angusta, P. suborbiculata and P. pseudolinearis. Monospores were liberated between 10°

and 25°C in P. tenera, P. yezoensis and P. angusta, and liberation of spores was little or not seen in P. kuniedai, P. suborbiculata and P. pseudolinearis at these temperature ranges. Kurogi et al., (1967) noticed differences in the optimum temperature of monospore liberation between the conchocelis occurring in the autumn and spring plants of Porphyra umbilicalis. Subba Rangaiah, (1978) and Umamaheswara Rao and Subba Rangaiah, (1980) observed variation in the liberation of tetraspores at 5 different temperatures ranging from 15°C to 35°C in Gracilaria corticata, Gracilaria textorii and Hypnea musciformis. Similarly the tetraspore output also varied at 9 different temperatures ranging from 0 - 45°C in the tetrasporic thalli of Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis as observed by Umamaheswara Rao and Kaliaperumal, (1983). Peak output of spores was noticed at 25°C in Gelidium pusillum and Pterocladia heteroplatos and at 30°C in Gelidiopsis variabilis. Similarly Umamaheswara Rao and Sanjeeva Reddy, (1982) observed maximum liberation of tetraspores from 25°C to 30°C in Dictyota dichotoma.

2.8 GERMINATION OF SPORES :

Some workers observed germination of spores in different seaweeds. Barilotti and Silverthorne (1972) observed seasonal spore germination in Gelidium robustum from Baja California. Fruiting plants were seen throughout the year and spores liberated during the spring and early summer were germinated producing young thalli on new substrata. In Chondrus crispus maximum germination rate was observed in the early fall. Subba Rangaiah (1978) also observed monthly variation in the number of dividing tetraspores and carpospores in Gracilaria corticata and Hypnea musciformis liberated on the first day and spore germination within 24 hours from December 1974 to April 1976. Kaliaperumal, (1979) collected some preliminary data on the percentage frequency of germinating tetraspores and carpospores in Gelidium pusillum and tetraspores in Pterocladia heteroplatos. He did not observe dividing spores within 24 hours in Gelidiopsis variabilis during the two and a half years seasonal study on spore germination.

Spore germination have been shown to be influenced by environmental factors such as desiccation, salinity, light and temperature by some workers. In Gelidium pusillum and Pterocladia heteroplatos Kaliaperumal, (1979) found maximum spore germination in controls than when exposed to air. Subba Rangaiah, (1978) studied germination of spores of Gracilaria corticata, and Hypnea musciformis in different salinities, Kaliaperumal (1979) found maximum germination of tetraspores of Gelidium pusillum in 20 ‰ and 30 ‰ whereas there was no germination in the tetraspores of Pterocladia heteroplatos.

The effect of light intensity on the germination of corpospores of Gracilaria verrucosa was studied by Jones (1959). The same study was also done by White and Boney (1969(in Acrochaetium endophyticum, by Subba Rangiah (1978) in Gracilaria corticata and Hypnea musciformis, by Kaliaperumal (1979) om Gelidium pusillum and Pterocladia heteroplatos. Katada (1949 and 1955) observed the effect of temperature on germination of carpospores and tetraspores in Gelidium amansii. Further studies on this aspect was done by Fukuhara, (1958) in Iridophycus cornucopiae, by Ohno, (1969) in Gelidium amansii, by Subba Rangaiah, (1978) in Gracilaria and Hypnea from Visakhapatnam coast, by Kaliaperumal, (1979) in Gelidium pusillum and Pterocladia heteroplatos.

CHAPTER - 3

MATERIAL AND METHODS

Mandapam (79°8'E, 9°17'N) is situated on the southern part of the East coast of India (Fig.1). To the north of Mandapam is Palk Bay and to the south the Gulf of Mannar. The coastline is sandy with boulders and platforms of compressed sand stones with rough and uneven surfaces occuring at different places with luxuriant dense growth of algae (Plate 1 A, B, C, D). The present sporulation study was made by collecting the plants fortnightly during the spring tide periods from three stations in the Gulf of Mannar side namely Thonithurai, Pudumadam and Kilakkarai (Fig.1). From Kilakarai (79°47'E, 9°12'N) tetrasporic plants of Gelidiella acerosa (Forsskal) Feldmann et Hamel were collected from the reef situated in the subtidal region and cystocarpic plants of Hypnea musciformis (Wulfen) Lamouroux from the rocks in the intertidal region. Collections of tetrasporic and cystocarpic plants of Gracilaria corticata J. Agardh and Hypnea musciformis were made from the rocks in the intertidal region at Pudumadam.

Tetrasporic and cystocarpic plants of Gracilaria edulis (Gmelin) Silva were collected from the subtidal region at Thonithurai (79°E, 9°16'N). Plates (2-8) show the photographs of the specimens of the above four red algal species. The material collected from all these stations were brought to the laboratory in polythene bag containing sea water and they were used for spore liberation studies.

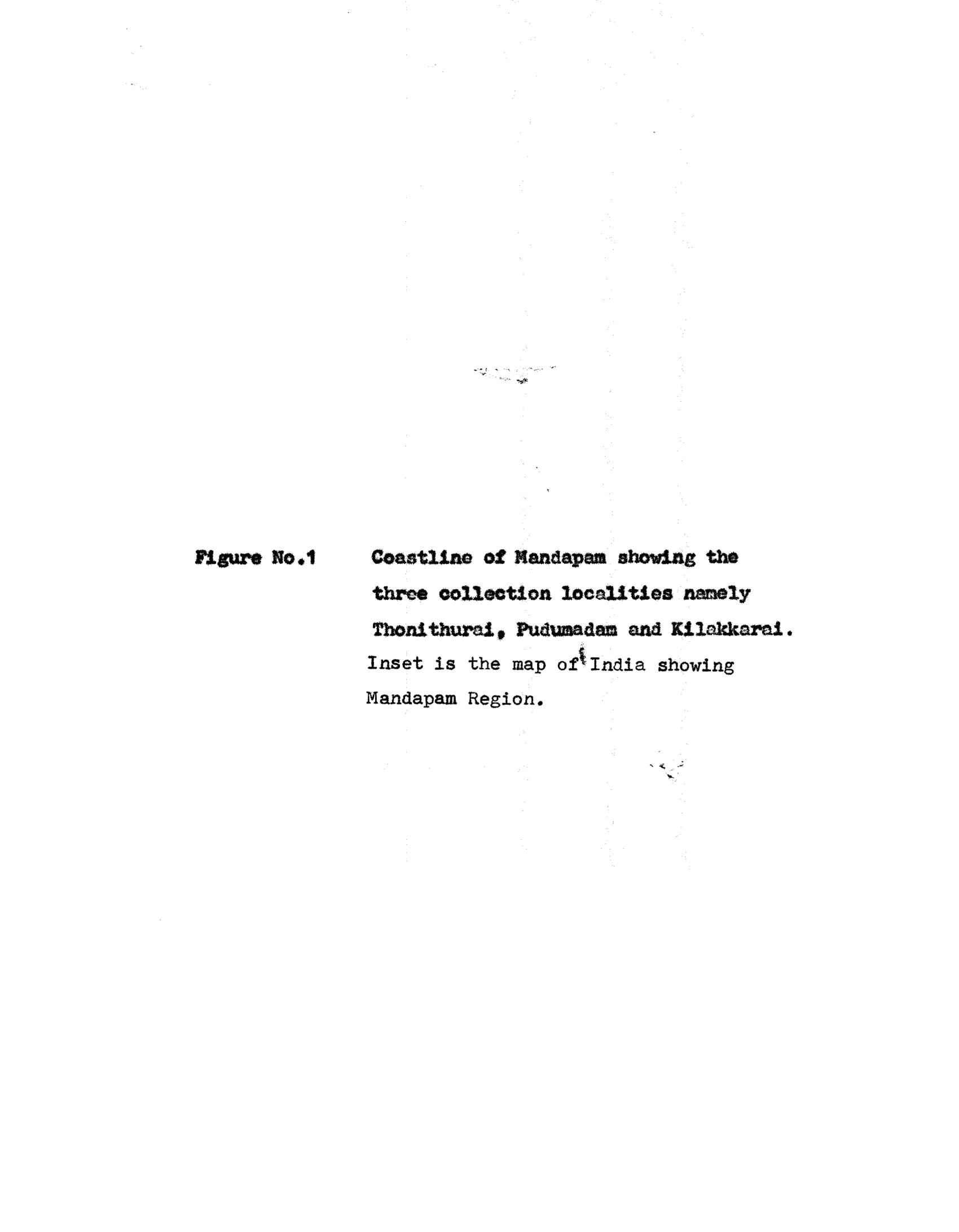


Figure No.1 **Coastline of Mandapam showing the three collection localities namely Thonithurai, Pudumadam and Kilakkarai.** Inset is the map of India showing Mandapam Region.

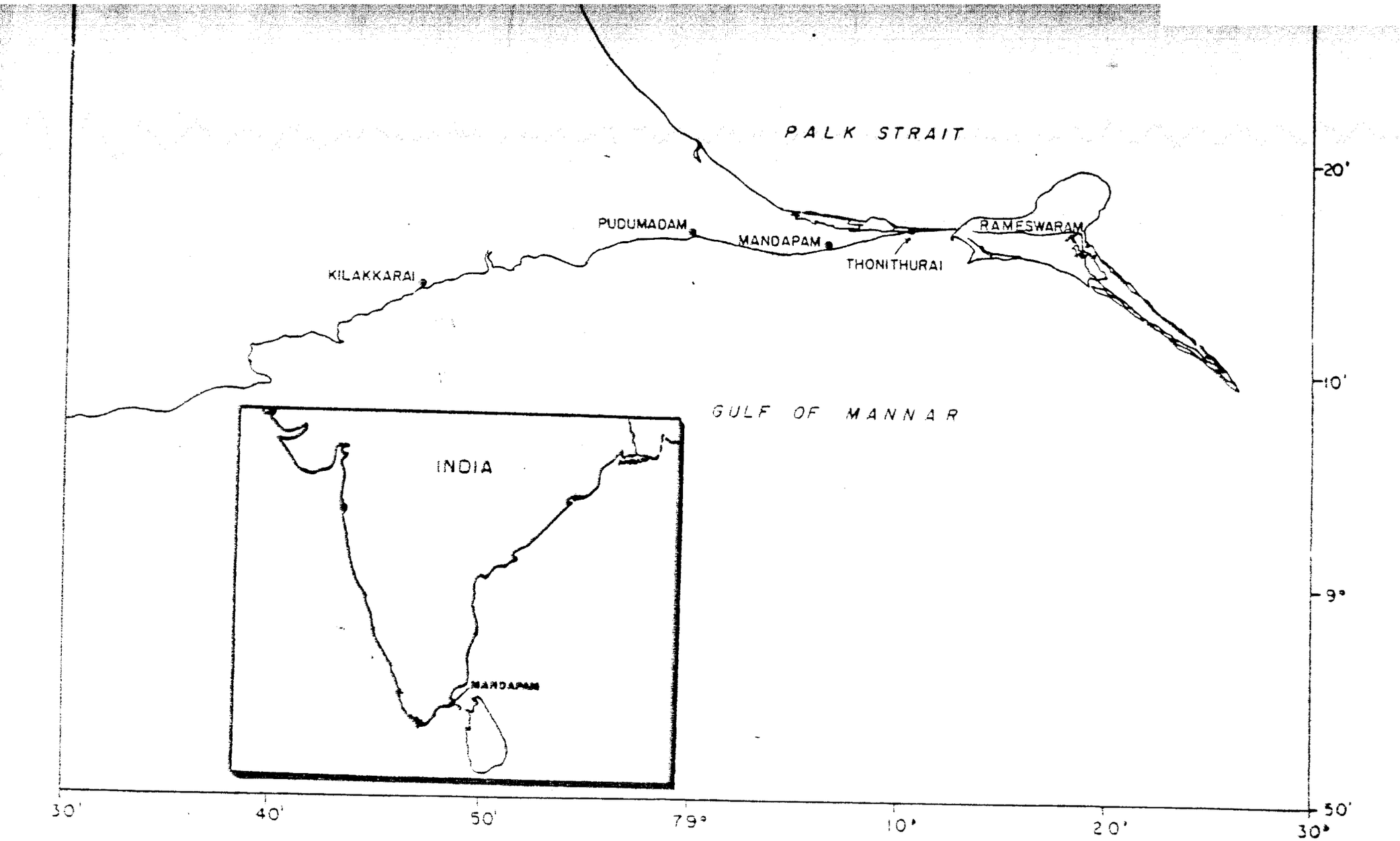
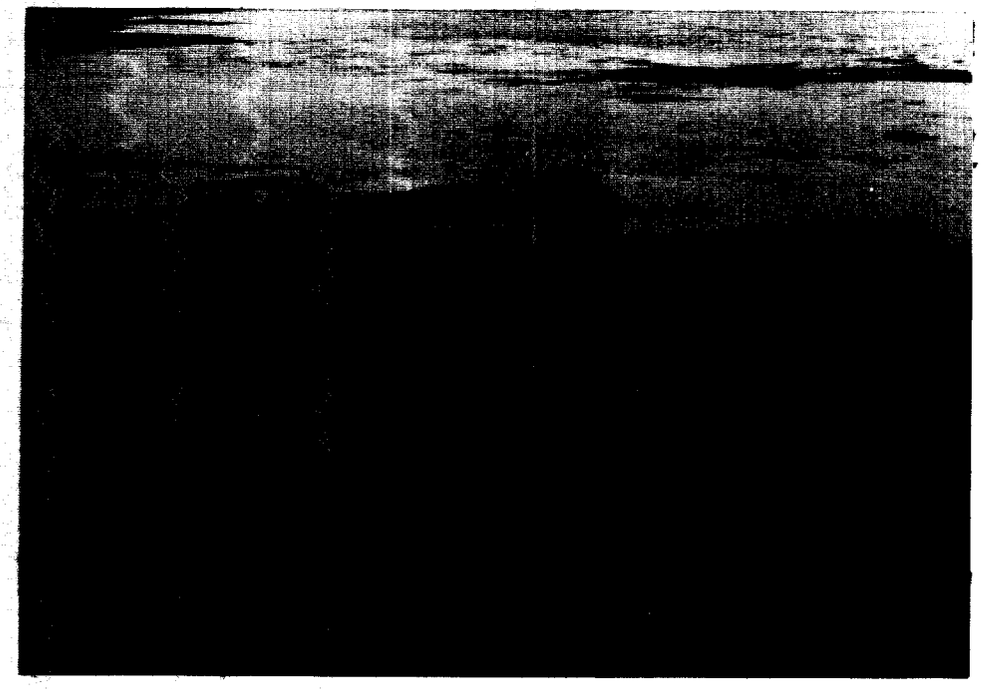
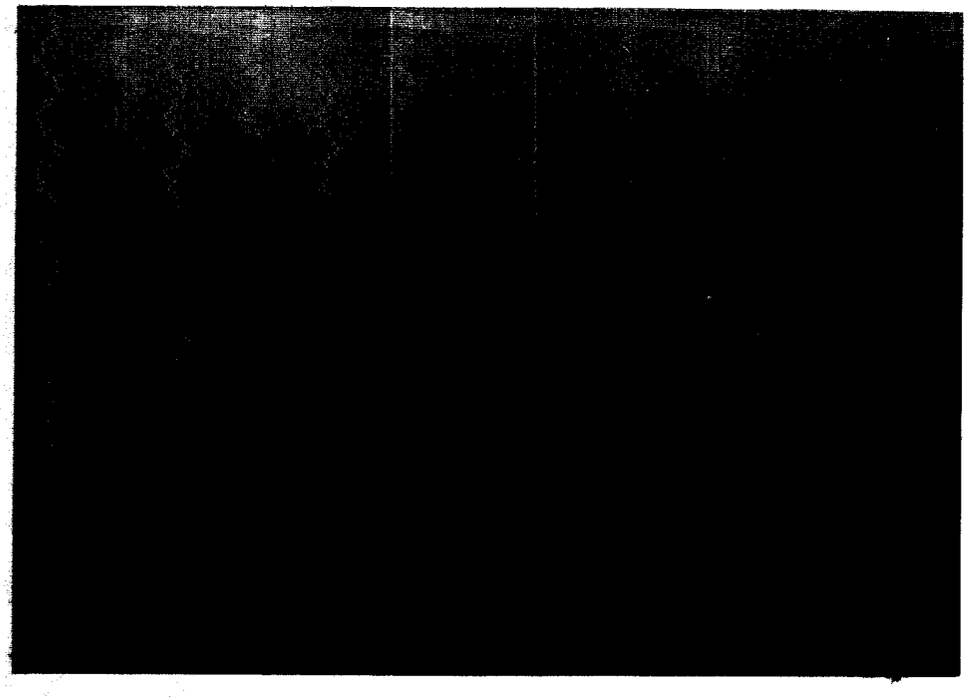

PALK STRAIT
PUDUMADAM
MANDAPAM
RAMESWARAM
THONITHURAI
KILAKKARAI
GULF OF MANNAR
INDIA
MANDAPAM
20'
10'
9°
50'
30'
40'
50'
79°
10'
20'
30'

Plate No.I (A-D) Thonithurai coast showing boulders and platforms of compressed sand stones with seaweed growth.

PLATE_I.



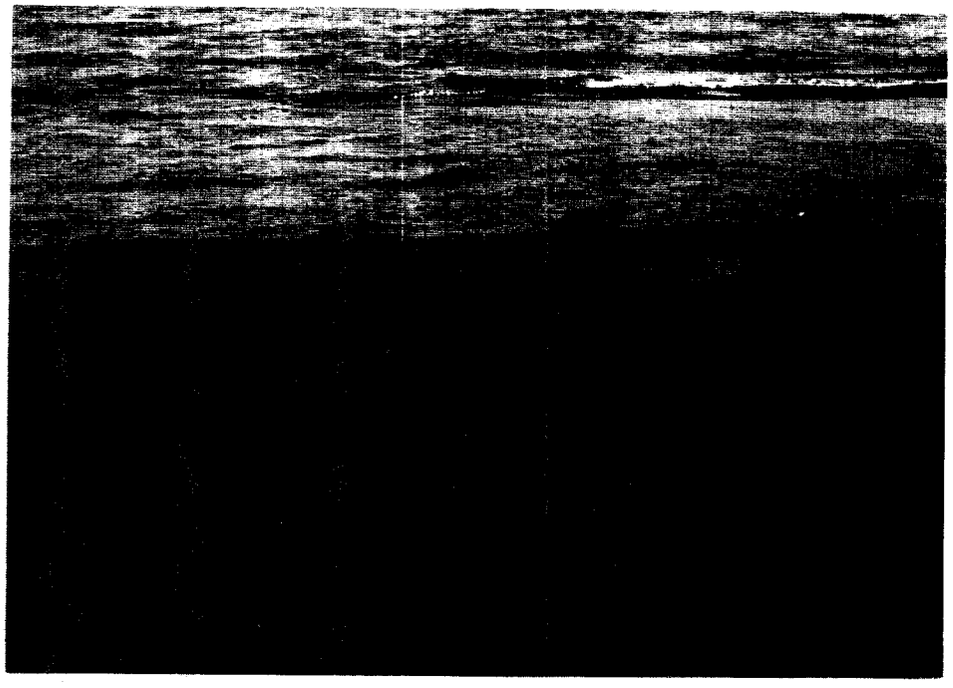
A



B

PLATE_I.

C



D

3.1 SPORE OUTPUT

Tetrasporic thalli of all the four red algae and cystocarpic thalli of Gracilaria corticata and G. edulis were used in experiments carried out to study the seasonal changes in spore output, diurnal periodicity and also the effects of environmental factors. Cystocarpic plants of Hypnea musciformis were not available in all months of the year. Depending upon the availability of carposporophytes, information was collected on seasonal and diurnal aspects of carpospore shedding of this species. However, experiments on the effects of selected environmental factors on carpospore output of Hypnea musciformis were conducted during the months when cystocarpic plants were available.

Small clumps of Gelidiella acerosa with well developed stichidia and 5-6 cm long fronds of Gracilaria corticata, G. edulis and Hypnea musciformis with well developed tetrasporangial sori and mature cystocarps were used for each spore shedding experiment. The materials thus selected for the experiments were cleaned and washed several times in sterile sea water. The thalli bearing fertile ramuli or stichidia of Gelidiella acerosa were placed in petri dishes of 5 cm diameter containing 20 ml of sterile sea water (Plate 9A) and fertile (tetrasporic and cystocarpic)

fronds of Gracilaria corticata, G. edulis and Hypnea musciformis in 9 cm diameter petri dishes filled with 50 ml of sterile sea water (Plate 9B & 9C). For estimating the spore producing capacity in the laboratory at room temperature the experimental sets were illuminated with a light source of 500 lux for 8 : 16 LD cycle(Plate 9A,B & C) For collecting the information on the seasonal spore output the spores liberated in the petri dishes were counted after 24 hrs every day and for diurnal spore output, spores liberated into the petri dishes at different times of the day i.e. at 4 hrs intervals from 2 PM onwards were counted. Tetraspores and carpospores liberated in the petri dishes were counted, as given below :

3.2 SPORE COUNT

At the end of each experiment, the liberated spores in the sea water in each petri dish were mixed thoroughly with a fine brush and the spore suspension transferred to a measuring cylinder (50 ml, 100 ml or 250 ml). The volume of the spore suspension was adjusted to 20 or 25 ml for Gelidiella acerosa and 50 or 60 ml for Gracilaria corticata, G. edulis and Hypnea musciformis using washings of the petri dish and sterile sea water. When spore shedding was high, the spore suspension was diluted upto 50 ml or 100 ml or 250 ml. A sub sample of 1 ml of the spore suspension was

then pipetted out into a plankton counting chamber and the spores present in all the squares of the chamber were counted with the help of hand tally counter under a monocular microscope. The degenerating spores were not counted. From the mean value of two counts and the total volume of the spore suspension, the spore output from the fruiting material was estimated. Depending on the availability of the tetrasporic and cystocarpic plants two or four experiments were conducted separately in a month for collecting data on seasonal and diurnal spore output. Fresh weight of the fronds of these four red algae were noted at the end of each experiment for computing their spore output per gram fresh weight of the plant. For Gelidiella acerosa fresh weight of 5 clumps and the total number of stichidia occurring on each clump were recorded every time to estimate the number of reproductive ramulii per gram fresh weight of the plant material. The procedures followed for seasonal and other studies on spore output are outlined as given below :

3.3 SEASONAL CHANGES IN SPORE OUTPUT :

Every month four experiments were conducted with Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis from October 1981 to September 1983 to understand the seasonal changes in sporulation. The tetraspores and carpospores liberated daily (every 24 hours) till the plants discharged spores upto a maximum of 30 days were counted to know the variations in the output of tetraspores and carpospores in different days under laboratory conditions. The total number of spores liberated at different days from the plants collected every month was used for estimating the seasonal changes in the spore output and it is expressed as spores per gram fresh weight of the sporulating thalli.

3.4 DIURNAL PERIODICITY IN SPORE OUTPUT :

Information on the diurnal changes on spore shedding was collected by changing the material at every four hours from one petri dish to another containing sterile sea water. These diurnal changes in spore production were studied for two years from October 1981 to September 1983 for the tetraspores of Gelidiella acerosa, and for the tetraspores and carpospores of Gracilaria corticata and G. edulis and Hypnea musciformis. The diurnal rhythm in the liberation of carpospores in Hypnea musciformis was observed for one year only from August 1982 to July 1983 from Pudumadam area.

Data could not be collected on the diurnal periodicity of tetraspore output in Gelidiella acerosa, Gracilaria corticata and Hypnea musciformis for the month of December, 1981.

The spores liberated at four hour intervals i.e. between 2 PM and 6 PM ; 6 PM and 10 PM ; 10 PM and 2 AM ; 2 AM and 6 AM ; AM and 10 AM and 10 AM and 2 PM were counted as stated earlier and the data are presented as the percentage of spores per gram fresh weight of the fruiting thalli. The materials were collected during the spring tide period of every month and both seasonal and diurnal experiments were commenced at 2 PM. These experiments were conducted at room temperature in the laboratory (29 $\pm$ 3 ^{o}C) and at light intensity of 00 lux during the day time for 8 hours from 10 AM to 6 PM. .e. 8 : 16 LD photo regime.

5 EFFECTS OF ENVIRONMENTAL FACTORS ON SPORE OUTPUT :

or assessing the effects of various environmental conditions 9 experiments were conducted for each factor. The methods dopted for each factor is described in the following aragraphs.

3.5.1 EXPOSURE TO AIR OR DESICCATION :

For studying the influence of desiccation or exposure to air, fertile fronds of Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis were exposed to air in the laboratory. Before exposing to air, the materials were washed off any foreign particle and then blotted with the blotting paper. The materials exposed to air upto eight hours in the laboratory (from 15 minutes, 30 minutes and 1 hour intervals) were then transferred to the petri dishes containing sterile sea water. Fronds that were kept throughout the period of the experiment in submerged conditions were used as controls. The spores liberated were counted next day after 24 hrs. While conducting these experiments, the laboratory room temperature varied from 26.5 ^{o} to 34.3 ^{o}C and the relative humidity varied from 50 % to 87 %. The relative humidity was found out with the help of a hygrometer. The experiment was conducted under a light intensity of 500 lux and 8 : 16 photo regime.

3.5.2 SALINITY :

A stock solution of 100 o/oo salinity was prepared by evaporating the sea water collected from the inshore area of Mandapam and estimating the salinity following the Winkler's volumetric method of Strickland and Parsons(1968). The stock solution was sterilised and used for experimental work. From this stock solution the lower salinity grades were prepared by adding requisite quantity of distilled water. The spore output in the four algae was estimated at 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 o/oo salinity by maintaining the petri dishes at room temperature and providing 500 lux day light fluorescent illumination for 8 hours and 16 hours dark cycle.

3.5.3 LIGHT INTENSITY :

Light intensity experiments were carried out at 6 different illuminance values (0, 500, 1000, 2000, 3000 and 4000 lux) and the petri dishes containing fruiting materials were subjected to 24 hour light cycle for sporulation.

.5.4 PHOTOPERIOD :

he combined effect of three different light intensities
500, 2000 and 4000 lux) and day length on spore shedding
f the four red algae were studied. The petri dishes
ontaining the fruiting fronds (tetraspores and carpospores)
mmersed in sterile sea water were subjected to 24 hours
ark (0 : $\overline{24}$) and light (24 : $\overline{0}$) cycle with 4 hours interval
.e. 0 : $\overline{24}$, 4 : $\overline{20}$, 8 : $\overline{16}$, 12 : $\overline{12}$, 16 : $\overline{8}$, 20 : $\overline{4}$ and
4 : $\overline{0}$ using three light intensities.

.5.5 TEMPERATURE :

he influence of 10 different temperatures :-
15 °, 0 °C, 5 °C, 20 °C, 25 °C, 30 °C, 35 °C, 40 °C, 45 °C
nd 50 °C on spore shedding was studied by maintaining the
etri dishes for 24 hours in a temperature controlled dark
ven or refrigerator or deep freezer. In all these experi-
ents on different factors the spores liberated in the petri
ishes were counted after 24 hours and the spore output was
xpressed as spores per gram fresh weight per day.

.6 GERMINATION OF SPORES :

hile counting the spores in various experiments planned
n this study, data on the germinating spores were also
ollected separately. The frequency of these germinating
pores (within 24 hours of their liberation) in different

months of the year and also in the experiments conducted to study the effects of exposure to air, salinity, light intensity, photoperiod and temperature on spore shedding.

3.7 SEASONAL CHANGES IN THE HYDROGRAPHICAL PARAMETERS :

In an attempt to determine the seasonal fluctuations in the hydrographical parameters in the localities from where materials have been obtained, fortnightly data were collected from October 1981 to June 1983 on the surface sea water temperature, pH, salinity and dissolved oxygen, while collecting the materials. The surface sea water temperature was measured and the atmospheric temperature in the field was also recorded simultaneously. Water samples were collected from each collection spot for analysis of pH, salinity and dissolved oxygen. For estimation of dissolved oxygen, the water samples were fixed with 1 ml of $MnCl_2$ (Winkler A) and 1 ml NaOH + KI (Winkler B) solutions immediately after collection on the field. In the laboratory, pH of the sea water collected from the work spots was found out with a pH meter. The salinity and dissolved oxygen of the sea water were estimated by standard methods given by Strickland and Parsons (1968).

CHAPTER - 4

RESULTS

Results obtained on the fruiting behaviour, daily and monthly changes in spore output, diurnal periodicity in the production of spores and the effects of environmental factors such as desiccation, salinity, light (intensity and photoperiod) and temperature on spore shedding in the four red algae of Mandapam coast namely Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis are presented here. The data collected on hydrographical aspects such as temperature, salinity, pH and dissolved oxygen and also atmospheric temperature recorded from the three collection localities namely Thonithurai, Pudumadam and Kilakarai are also presented in this chapter.

4.1.1 FRUITING BEHAVIOUR :

Population of Gelidiella acerosa at Kilakarai, Gracilaria corticata at Pudumadam, G. edulis at Thonithurai and Hypnea musciformis at Pudumadam and Kilakarai in the vicinity of Mandapam occurred throughout the year. Tetrasporic plants of all these four species were found continuously from October 1981 to September 1983. Cystocarpic plants of Gracilaria corticata and G. edulis

occurred in all months of the year. During the two year period October 1981 - September 1983, carposporophytes of Hypnea musciformis at Pudumadam occurred only for 13 months from August 1982 to July 1983 and September 1983 and at Kilakarai except in November and December 1981 and January and June 1982 they occurred in the other twenty months. Cystocarpic plants of Gelidiella acerosa were not found during the entire period of the study.

4.1.2 MORPHOLOGICAL APPEARANCE OF THE FRUITING FRONDS OF THE FOUR SPECIES OF AGAROPHYTES :

The identification of cystocarpic and tetrasporic thalli in the field with the ordinary eye is most desirable for one to be able to facilitate the process of collecting the fertile thalli to be used in the sporulation studies.

The "fruiting" thalli of the four algal species, are shown in plate (2 - 8) and figures, (2E - 2H). The tetraspores are produced by a tetrasporic thallus and carpospores by a cystocarpic frond.

Cystocarpic Plants

In all the species described the carpospores are produced in swollen sessile hemispherical structures

with dark red, brown contents, known as "cystocarps" which are borne singly or in an aggregation of two, three or five cystocarps. These occur all over the surface of the thallus and also close to the thallus apex. The cystocarps observed in Gracilaria corticata, G. edulis and Hypnea musciformis vary in size and may attain a diameter of up to 0.5 mm to 0.9 mm and 1.0 mm to 1.2 millimeters. Cystocarps are (Fritsch, 1945) part of the carposporophytic generation which develops parasitically on the female gametophyte. The morphological appearance of the cystocarpic plants is shown in plates 2 - 7 and Figures 2F and 2G.

Tetrasporic Plants

The tetrasporophytic thallus producing the tetraspores in Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis are shown in plate (2-7) and (Figures, 2E & 2H). In Gelidiella acerosa and Hypnea musciformis a fertile tetrasporophytic plant is distinguished on the basis of its swollen side branchlets which are then called as stichidial branches (Tanaka 1941) and from the presence of lack of any hemispherical swellings. The swollen region of the stichidia or ramullii, where the tetrasporangia are concentrated, is usually of a darker colour (Pink

brown in case of Gelidiella acerosa and darker brown in colour in Hypnea musciformis) than any portion of vegetative branchlets (Pate 2 & 7) and Figures 2E and 2H. In Gracilaria corticata the tetrasporangia are found all over the thallus just below the cortex and embedded in the cortex layer. The thallus is flattened as shown in Plate (3A and 4AB) with numerous dichotomous branches arising from the basal attachment. In G. edulis the thallus is cylindrical in structure, dark red, brown, green in colour with numerous fronds arising from the basal disc (Plate 5A & 6A). The tetrasporangia are borne on the tetrasporic fronds just below the cortex layer. In these species there is no specialised appendage as is found in Gelidiella acerosa and Hypnea musciformis.

The Gelidiella acerosa plants are thick wiry, mostly light brown dark brown to green in colour. The fronds are stiff, cartilaginuous show repeated pinnate branching (Fritsch, 1945) (Plate 2A, B and Figures 2E)

Hypnea Musiformis

It
(Plate 7A, B and Figure 2H), has fleshy terete thalli with numerous long and short branches and are incurled at the tip, with dark green, brown in colour.

Plate No.II A *Gelidiella acerosa*, habit.

(B-C) Tetrasporic thalli *G. acerosa* with stichidia. S - stichidia

PLATE _II.

A

B

C

Figure No.2.E Fruiting frond of <u>Gelidiella acerosa</u>, showing tetrasporangial stichidia. Arrow showing T-thalli, S-stichidia, b-branch, bl-branchlet

FIGURE_2E 1 and 2

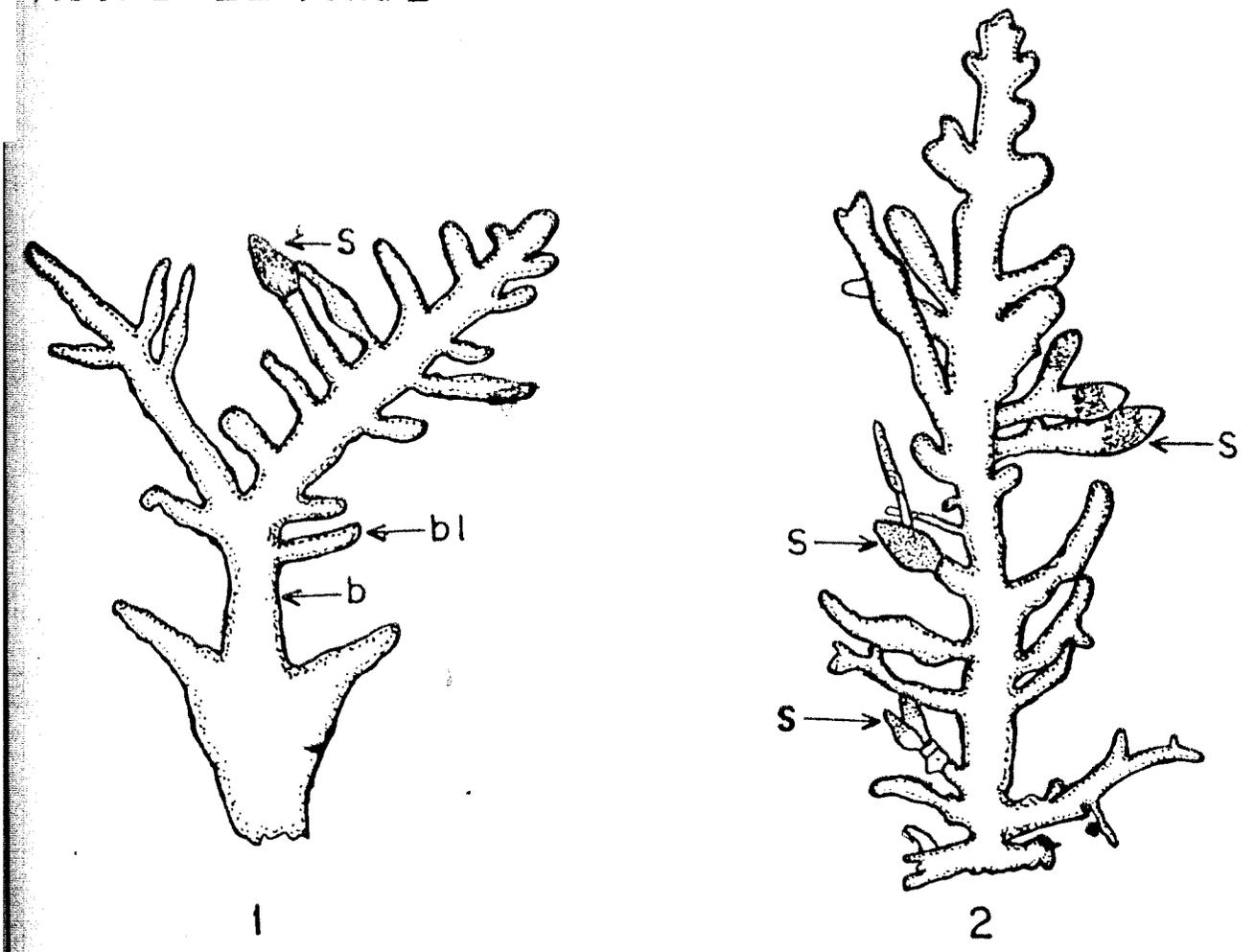
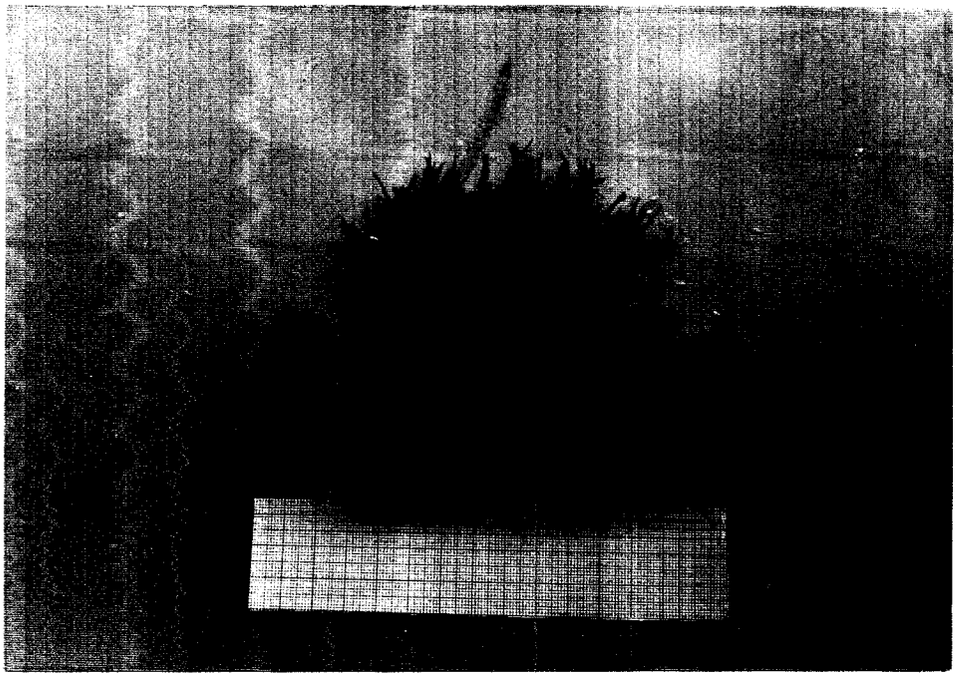


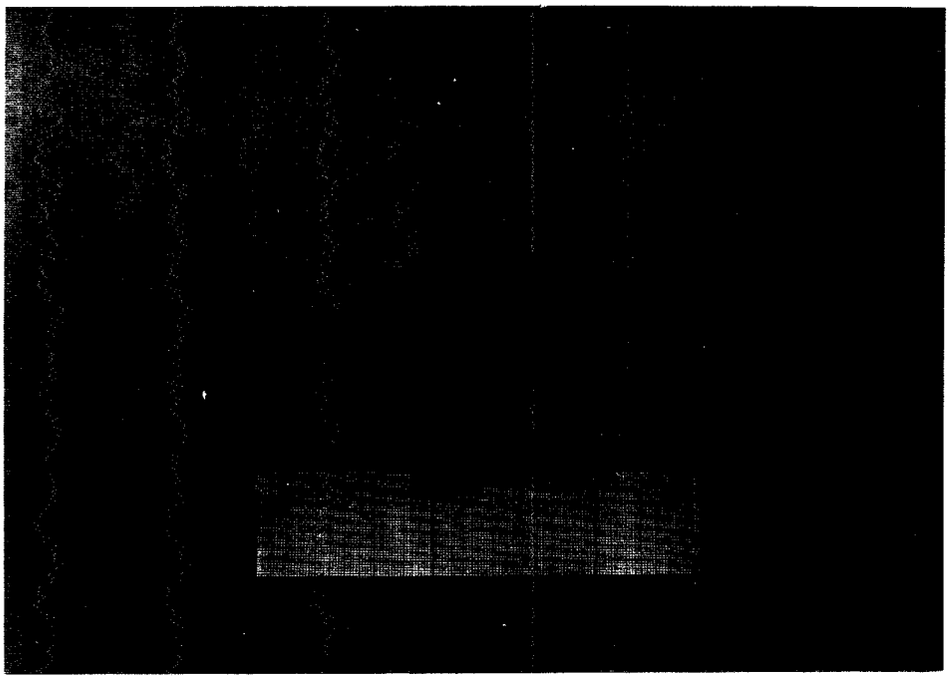
Plate No.III A *Gracilaria corticata* (tetrasporic) habit.

B *G. corticata* (cystocarpic) habit.

PLATE - III.



A



B

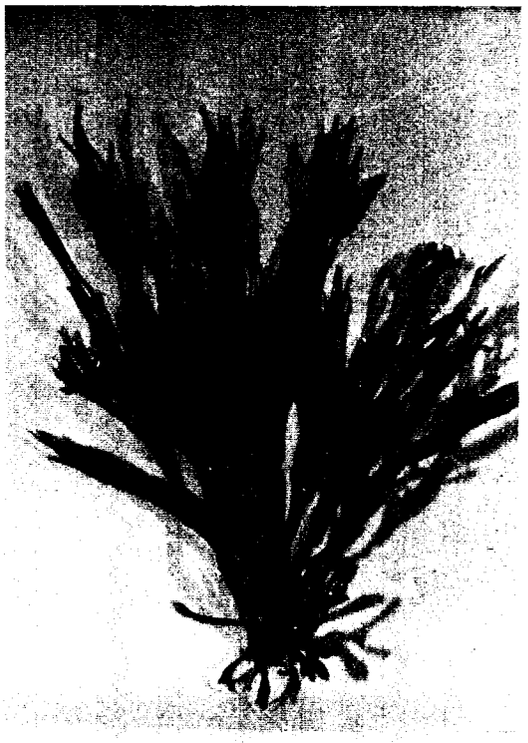
Plate No.IV A Gracilaria corticata (tetrasporic) habit.

B Tetrasporic thalli of G. corticata (magnified).

C Cystocarpic thalli of G. corticata.

D Cystocarpic thalli of G. corticata showing cystocarps. (c - marked arrow).

PLATE _ IV.



A

B

C

D

Figure No.2.F Cystocarpic frond of Gracilaria corticata showing the arrangement of cystocarps. Arrow showing C-cystocarps, T-thalli, b-branch, bi-branchlet, X 10.

FIGURE_2F

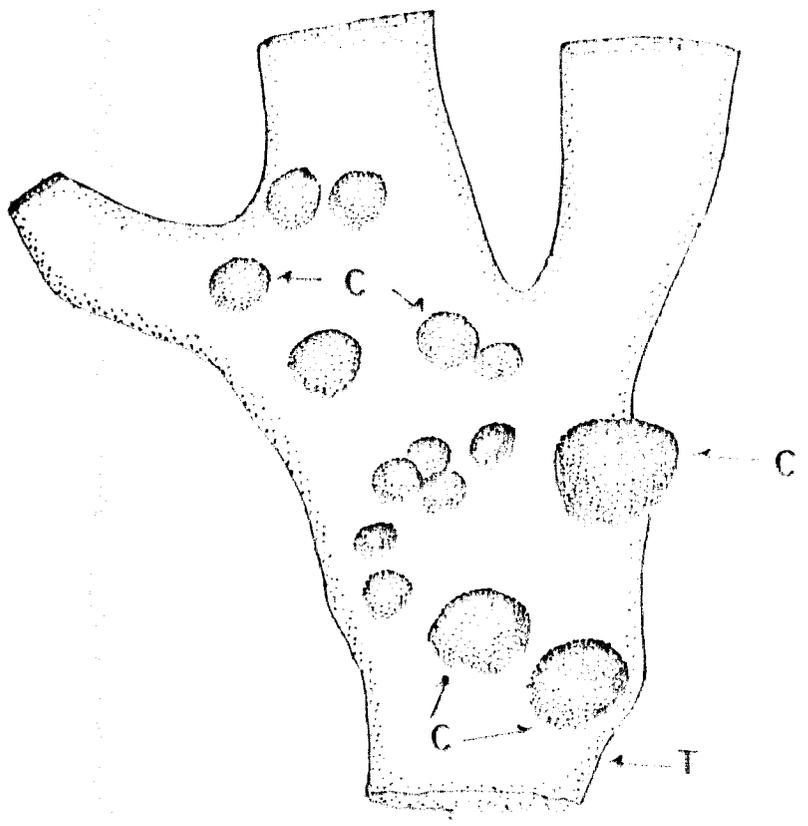


Plate No.VIII A Tetrasporic plant of Hypnea musciformis

B Cystocarpic plant of Hypnea musciformis with cystocarps.

PLATE_VIII.

A B

Figure No.2.H Part of a tetrasporic frond of Hypnea muciformis to show morphological appearance of tetrasporangial stichidia Arrow showing T-thalli, S-stichidia, B-branch, Bl-branchlet.

FIG. 2H. 1

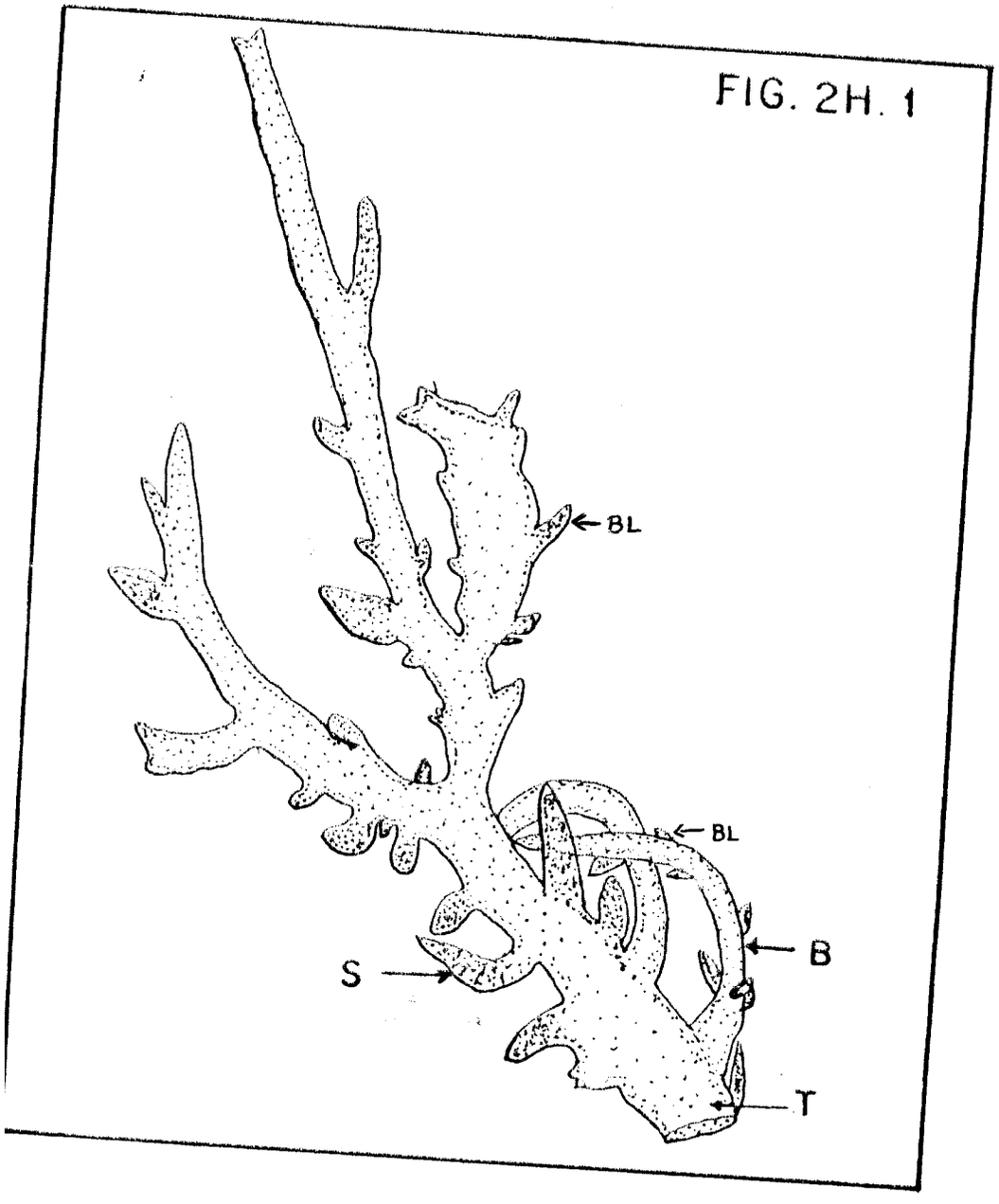


FIG. 2H 2

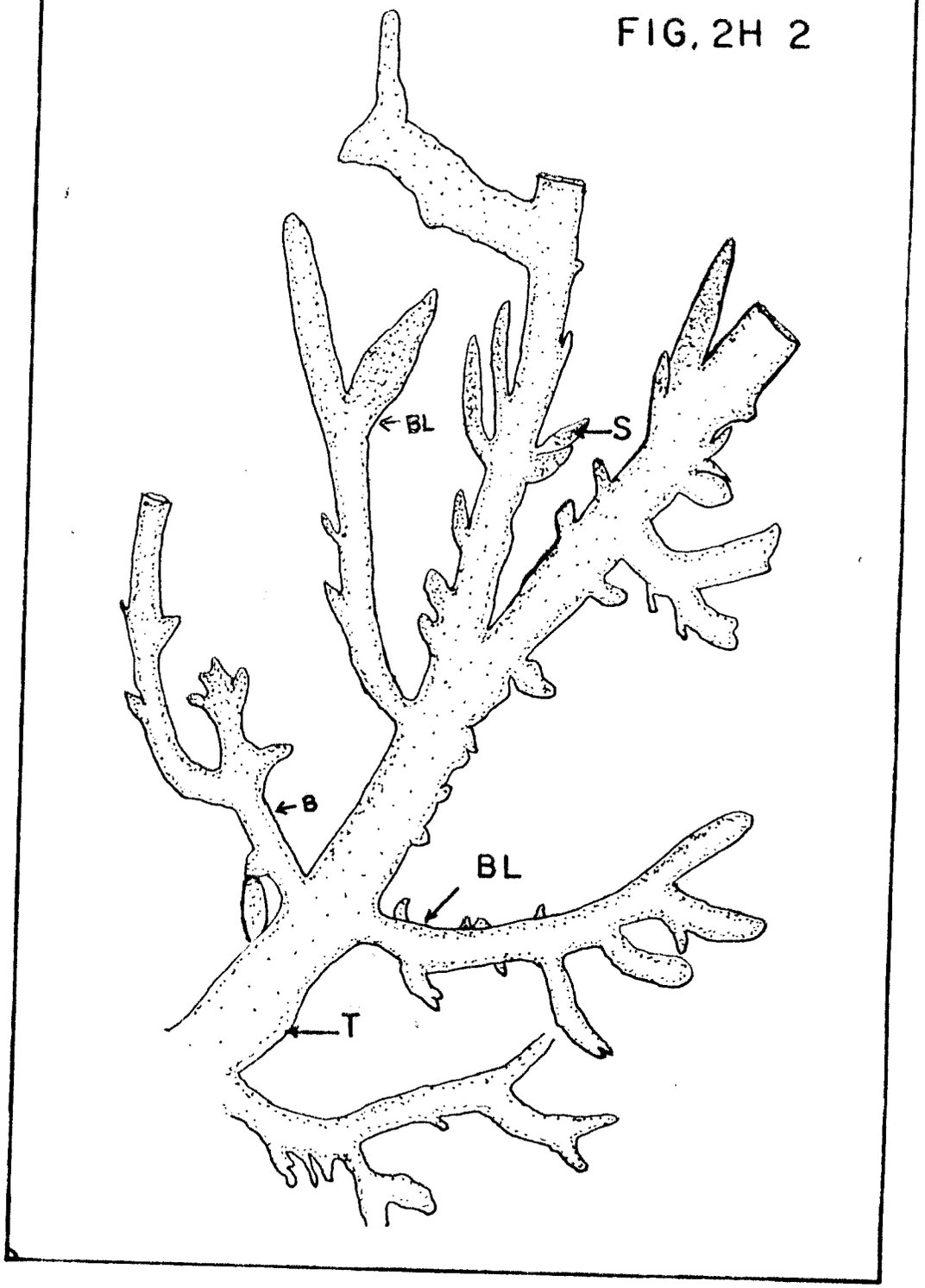
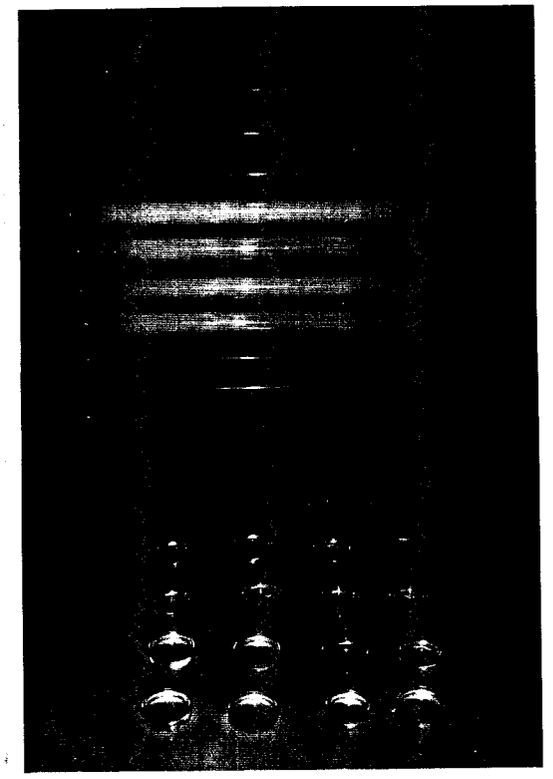
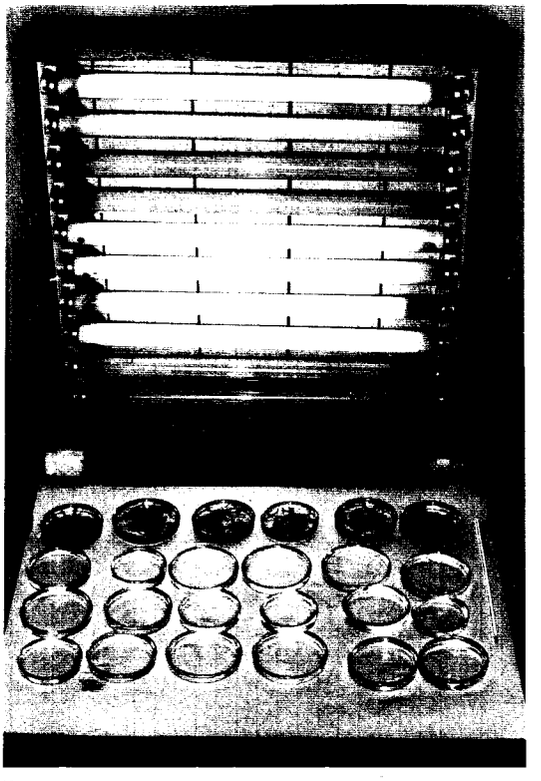


Plate No.IX Experimental sets kept for sporulation studies.

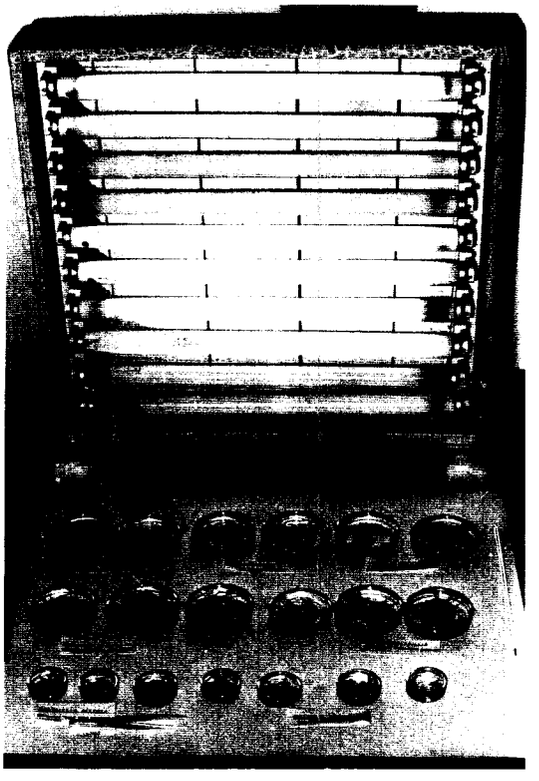
PLATE_IX.



A



B

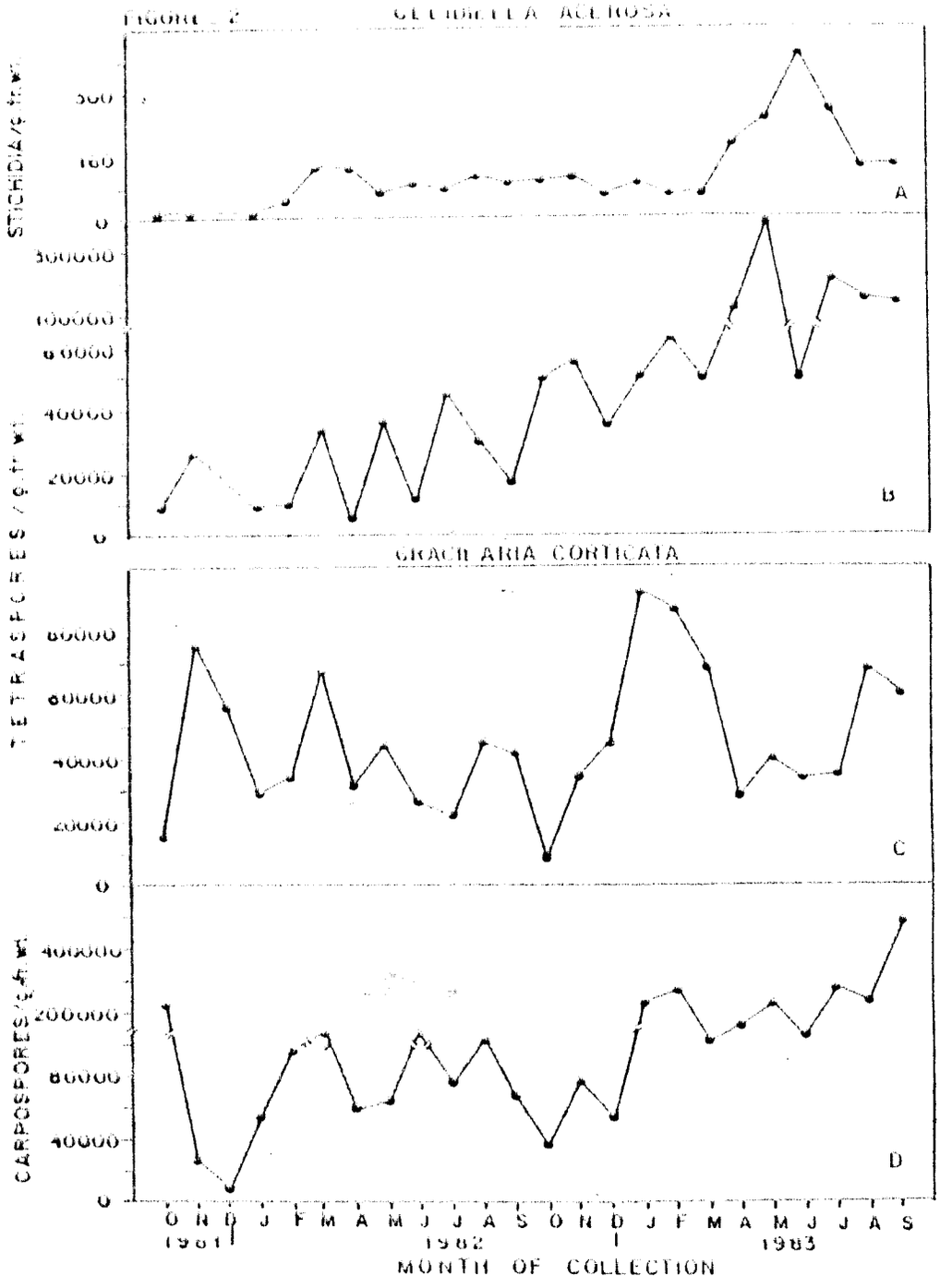


C

4.2 SPORE OUTPUT :

Tetraspore output at different days during various months of the years were studied in Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis are presented in Tables 1-4 and that of carpospores in Gracilaria corticata, G. edulis and Hypnea musciformis are given in Tables (5-8) to show the trend in the daily liberation of spores. In the four algae studied maximum shedding of both tetraspores and carpospores were seen on the first day almost in all the months. The tetraspore output decreased from 2nd day onwards (Tables 1-4) whereas carpospores were liberated rhythmically with peaks at intervals of different days in many months (Tables 5-8). To show the rhythmic liberation of carpospores in Gracilaria corticata, G. edulis and Hypnea musciformis, the data for few months from Tables 5 to 8 where this trend is clear are plotted in Fig. 2&3 Under laboratory conditions tetraspore out-put was seen from 6-14 days in Gelidiella acerosa, 3-27 days in Gracilaria corticata, 3-30 days in G. edulis and 3-23 days in Hypnea musciformis during different months of the year (Tables 1-4). Shedding of carpospores is found for 6-30 days in Gracilaria corticata, 10-30 days in G. edulis and 2-24 days in Hypnea musciformis

Figure No.2 Seasonal variation in stichidia (A) and tetraspores (B) of Gelidiella acerosa and tetraspores (C) and Carpospores (D) of Gracilaria cortica


GELIDIELLA ACEROSA
GRACILARIA CORTICATA
STICHIDIA/6 fields
TETRASPORES/6 fields
CARPOSPORES/6 fields
A
B
C
D
O N D J F M A M J J A S O N D J F M A M J J A S
1981
1982
1983
MONTH OF COLLECTION

(Tetraspores/g. fr. wt./day)

Month of Collection	Number of days														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. October '81	5491	2306	705	299	64	60	33	10	0						
2. November '81	13126	8613	4314	444	167	218	152	16	16	25	32	0			
3. December '81 (No Data)	-	-	-	-	-	-	-	-	-	-	-	-			
4. January '82	6264	1305	943	795	570	308	110	0							
5. February '82	5492	3904	137	148	100	62	30	35	0						
6. March '82	18520	10707	3331	1017	314	123	0								
7. April '82	4063	961	401	253	36	30	0								
8. May '82	27103	7414	1221	863	253	81	26	0							
9. June '82	8995	1272	689	217	104	63	80	0							
10. July '82	25660	11570	7024	770	244	23	9	0							
11. August '82	17596	5989	3891	1139	861	496	115	34	10	0					
12. September '82	12240	2177	1091	800	738	117	129	212	100	155	125	79	65	3	0

(Contd..... 2.)

Table-1. (Contd...2.) Tetraspore Output at different days in Gelidiella acerosa collected from Kilakkarai (Tetraspores/g. fr.wt./day)

Month of Collection	Number of days														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13. October '82	36761	7181	2842	1970	656	215	143	193	130	101	23	0			
14. November '82	43829	6402	3122	936	710	313	161	15	0						
15. December '82	27388	4205	1683	713	183	96	135	87	172	115	28	0			
16. January '83	38874	6197	2298	976	928	318	277	177	68	156	21	10	0		
17. February '83	49379	10119	1720	933	197	13	0								
18. March '83	36415	6836	3219	2717	997	122	0								
19. April '83	99334	11825	6954	2038	618	128	157	72	0						
20. May '83	215859	120787	40272	8991	3518	320	46	0							
21. June '83	39951	7202	1772	821	420	223	68	0							
22. July '83	141536	50784	12722	3362	602	58	0								
23. August '83	103882	31660	8666	4184	2054	274	0								
24. September '83	92387	32670	8606	3072	1034	298	153	652	655	138	0				

(Tetraspores/g. fr.wt./day)

Month of Collection		Number of days													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. October	'81	10325	1907	729	203	284	150	250	84	37	83	23	23	40	76
2. November	'81	39079	30379	365	925	932	953	631	268	1145	190	0			
3. December	'81	34536	13500	7810	139	82	18	34	51	13	3	10	0		
4. January	'82	8984	5064	710	10452	1660	1046	928	0						
5. February	'82	14370	7226	7909	4217	36	24	95	157	284	5	8	0		
6. March	'82	52855	4582	7828	2279	14	11	2	21	0					
7. April	'82	2445	598	379	299	11933	30	0							
8. May	'82	29786	6506	4966	1090	74	109	127	192	128	16	18	25	23	52
9. June	'82	14074	4004	4057	3414	355	165	57	53	53	33	20	15	10	6
10. July	'82	17498	2652	345	115	212	31	21	23	81	251	47	25	70	79
11. August	'82	32573	10056	403	379	236	143	108	103	294	116	103	10	129	41
12. September	'82	23374	10120	3359	2151	555	250	164	77	88	139	228	126	78	106

(Contd..... 2.)

(Tetraspores /g. fr. wt./day)

Month of Collection		Number of days													
		15	16	17	18	19	20	21	22	23	24	25	26	27	28
1. October	'81	22	103	5	36	9	33	25	11	6	185	0			
2. November	'81	–	–	–	–	–	–	–	–	–	–				
3. December	'81	–	–	–	–	–	–	–	–	–	–				
4. January	'82	–	–	–	–										
5. February	'82	–	–	–	–										
6. March	'82	–	–	–	–										
7. April	'82	–	–	–	–										
8. May	'82	18	8	11	120	85	104	151	36	54	6	8	7	0	
9. June	'82	20	16	0											
10. July	'82	34	20	56	75	122	28	30	69	37	0				
11. August	'82	17	31	28	30	32	38	48	65	93	126	38	0		
12. September	'82	164	75	91	44	20	87	215	139	182	207	40	15	10	0

(Contd..... 3.)

Pudumadam

(Tetraspores / g. fr. wt./day)

Month of Collection		Number of days													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
13. October	'82	5233	1339	233	675	125	120	300	96	50	8	2	0		
14. November	'82	15457	9728	3865	3072	539	193	385	182	241	141	302	86	49	31
15. December	'82	23592	13982	4714	690	804	285	379	353	499	119	51	2	0	
16. January	'83	48429	23062	4771	5571	3442	1587	120	544	691	955	573	503	275	690
17. February	'83	52695	15921	10879	1789	606	267	1237	3144	93	67	18	16	11	0
18. March	'83	44752	18332	2610	854	489	368	246	99	0					
19. April	'83	13963	6716	5472	1470	340	21	0							
20. May	'83	21148	12086	3441	2094	624	190	117	0						
21. June	'83	18865	10485	2801	380	148	117	95	17	2	0				
22. July	'83	21775	8380	3016	616	237	103	5	0						
23. August	'83	42653	10304	9915	3216	1488	499	293	0						
24. September	'83	36506	10954	6964	3530	789	178	32	0						

(Contd..... 4.)

Table – 2. (Contd..... 4.) Liberation of tetraspores at different days in Gracilaria corticata collected from Pudumadam

(Tetraspores / g. fr. wt./day)

Month of Collection	Number of days													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
13. October '82														
14. November '82	67	50	28	0										
15. December '82														
16. January '83	485	493	186	0										
17. February '83														
18. March '83														
19. April '83														
20. May '83														
21. June '83														
22. July '83														
23. August '83														
24. September '83														

(Tetraspores /g. fr. wt./day)

Month of Collection		Number of days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. October	'81	1889	130	116	0											
2. November	'81	25309	11736	1633	66	128	34	16	31	24	9	6	36	0		
3. December	'81	27784	14412	77	64	124	161	70	22	19	4	27	23	51	25	12
4. January	'82	1352	224	10	709	72	58	29	0							
5. February	'82	21174	1046	583	97	49	55	39	0							
6. March	'82	65213	41806	2227	152	80	32	10	14	29	2	0				
7. April	'82	19041	3316	1223	116	17	24	3	6	3	3	0				
8. May	'82	21966	1728	201	59	86	48	30	7	0						
9. June	'82	8776	2028	585	206	30	15	32	7	22	9	6	8	23	38	19
10. July	'82	61889	20451	8881	4623	3829	1092	647	467	236	153	305	333	346	240	447
11. August	'82	15096	2995	896	2847	1505	3888	84	62	24	117	76	217	114	129	122
12. September	'82	13518	4396	2247	1762	2094	870	129	857	222	333	131	100	80	19	0

(Contd..... 2.)

(Tetraspores/g. fr. wt./day)

Month of Collection		Number of days														
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1. October	'81															
2. November	'81															
3. December	'81															
4. January	'82															
5. February	'82															
6. March	'82															
7. April	'82															
8. May	'82															
9. June	'82	2	3	0												
10. July	'82	250	203	230	225	121	70	34	58	15	5	51	31	40	21	16
11. August	'82	158	134	149	77	107	0									
12. September	'82															

(Contd..... 3.)

(Tetraspores/g. fr. wt./day)

Month of Collection	Number of days														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13. October '82	15248	6923	5993	10336	2185	358	202	114	34	14	14	29	0		
14. November '82	13165	8886	4832	3837	3108	2193	260	113	66	11	6	290	132	42	7
15. December '82	21849	9232	9373	73	519	72	156	168	52	63	47	3	0		
16. January '83	43772	17819	12072	9303	4395	2438	1754	28	43	50	32	18	27	6	7
17. February '83	42355	31900	14097	8852	6648	3385	636	77	53	13	0				
18. March '83	39030	22159	8007	2320	977	414	229	44	11	10	0				
19. April '83	29982	16005	5352	2587	478	369	174	76	0						
20. May '83	30926	14148	2623	529	151	75	27	0							
21. June '83	27826	12234	5384	642	214	33	9	0							
22. July '83	22081	12519	4422	2546	963	405	110	0							
23. August '83	34090	16274	6852	2678	438	115	20	0							
24. September '83	31975	18415	3799	1358	836	210	0								

(Contd..... 4.)

(Tetraspores/g. fr. wt./day)

Month of Collection		Number of days													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. October	'81	38030	3946	13	188	0									
2. November	'81	11438	569	180	60	20	21	200	25	17	17	28	14	0	
3. December	'81	3033	246	366	202	103	21	15	7	0					
4. January	'82	40493	970	132	0										
5. February	'82	31495	4172	817	14869	3722	1746	3069	81	109	85	94	0		
6. March	'82	27029	34398	21260	93	0									
7. April	'82	1199	416	609	1065	535	116	184	34	0					
8. May	'82	332	569	534	247	359	309	179	133	0					
9. June	'82	61420	5370	575	956	182	121	48	18	0					
10. July	'82	44402	1234	237	573	393	376	150	510	191	26	6	45	74	11
11. August	'82	45556	12349	2569	588	1240	536	312	201	53	65	93	126	38	0
12. September	'82	56062	26593	6393	4759	4802	1481	1120	191	125	509	943	398	353	134

(Contd..... 2.)

(Tetraspores/g. fr. wt./day)

Month of Collection	Number of days													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1. October '81														
2. November '81														
3. December '81														
4. January '82														
5. February '82														
6. March '82														
7. April '82														
8. May '82														
9. June '82														
10. July '82	39	26	11	0										
11. August '82														
12. September '82	159	67	107	84	21	47	17	6	28	0				

(Contd..... 3.)

(Tetraspores/g. fr. wt./day)

Month of Collection			Number of days													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13.	October	'82	44206	10145	1886	1532	687	413	164	119	0						0
14.	November	'82	26264	7252	5967	1819	622	222	279	98	9	0					0
15.	December	'82	215137	113229	35779	11963	22317	1353	9369	844	190	0					0
16.	January	'83	255834	140262	40538	35147	24178	6637	2357	0							0
17.	February	'83	111378	54462	12137	4335	1226	2317	121	108	89	111	33	88	46	0	0
18.	March	'83	53021	22053	11502	7285	2640	2696	1997	829	0						0
19.	April	'83	104150	56425	16340	2550	606	111	0								0
20.	May	'83	98308	66532	16737	7756	1395	526	441	181	0						0
21.	June	'83	82667	23066	5258	4676	1774	365	0								0
22.	July	'83	45942	12787	3614	1160	215	63	0								0
23.	August	'83	119790	66850	17810	10290	7944	3500	1021	0							0
24.	September	'83	111792	101965	33756	66126	24240	6302	5113	0							0

(Carpospores/g. fr. wt./day)

Month of Collection		Number of days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. October	'81	17612	4899	8797	3263	5412	14911	20456	7112	3172	5420	3432	10332	9090	12113	11982
2. November	'81	3570	373	8444	12672	302	69	30	52	0	0	-				
3. December	'81	5372	1512	711	303	122	66	0	0	0	0	-				
4. January	'82	14363	2694	6571	25012	3945	556	866	69	0	0	-				
5. February	'82	37291	5125	12236	10644	3236	2524	1320	4223	1450	17967	446	0			
6. March	'82	46695	9599	2859	10662	17616	14923	5921	8269	2869	2390	963	620	412	469	714
7. April	'82	26556	7346	4722	6417	2873	4889	2065	1118	638	437	525	330	153	410	342
8. May	'82	20046	3511	2833	8698	10945	3120	2785	3655	2458	698	502	1418	248	145	1171
9. June	'82	34363	7693	2482	3700	5464	13506	13662	18500	16119	2702	2759	2267	959	1219	763
10. July	'82	16381	13181	6549	7568	2664	3003	1322	1548	1238	3297	6434	4462	5027	990	325
11. August	'82	27406	13668	6036	7464	7594	10175	2172	3562	16772	2236	1806	1300	2038	1677	1212
12. September	'82	20228	9378	3379	5189	3410	1410	685	1444	4174	1685	2833	1296	180	280	769

(Contd..... 2.)

(Carpospores/g. fr. wt./day)

Month of Collection	Number of days														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1. October '81	11608	27276	14590	4424	3033	4899	4672	5882	1465	1417	1494	702	2111	1092	489
2. November '81															
3. December '81															
4. January '82															
5. February '82															
6. March '82	300	3235	111	227	45	115	225	335	379	112	203	10	5	0	
7. April '82	473	592	185	131	167	102	61	0							
8. May '82	69	34	366	389	212	289	257	253	35	18	21	31	5	0	
9. June '82	1223	1148	673	305	475	435	918	269	302	297	259	144	0		
10. July '82	302	81	124	104	138	52	103	44	44	8	17	13	0		
11. August '82	569	472	501	197	256	116	50	29	15	13	12	7	6	0	
12. September '82	697	2205	359	1901	1119	521	562	340	385	631	170	310	144	0	

(Contd...., 3.)

(Carpospores/g. fr. wt./day)

Month of Collection	Number of days														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13. October '82	11167	3039	1290	1057	565	534	166	638	1757	1114	1023	514	253	65	38
14. November '82	24604	13865	2740	4461	4658	1010	2090	2852	3013	2622	4527	914	1481	1492	1839
15. December '82	12228	7907	5639	2350	6307	753	6813	6149	2997	1373	500	318	81	0	
16. January '83	69355	35675	13133	8365	14422	13512	2232	9015	4380	6287	6159	2566	2801	1647	2681
17. February '83	64761	29511	8632	5596	25892	43536	9425	3859	3906	340	1164	1945	1750	664	14732
18. March '83	41715	15906	20556	13931	3607	7755	6378	2790	166	0	0	0			
19. April '83	48673	25160	12042	26216	17251	4701	11233	8533	1794	0	0	0			
20. May '83	29979	19969	82051	24174	12771	14044	15748	8234	4295	3100	10110	3874	2455	2530	602
21. June '83	32032	7511	5153	9837	12975	6484	15563	4314	782	7543	2893	825	3437	9176	8894
22. July '83	38199	19375	17288	20185	3333	17931	2710	13509	13403	14563	11951	8283	19639	9915	2663
23. August '83	48686	20289	30166	15706	3286	18435	24731	3436	13325	2394	17589	2752	2992	7972	3279
24. September '83	52111	17885	26112	10432	41453	6025	1678	25666	25362	23047	16204	20968	19168	19306	14379

(Contd..... 4.)

(Carpospores/g. fr. wt./day)

Month of Collection		Number of days														
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
13. October	'82	125	298	2892	7167	627	274	437	155	410	108	0	0	0	0	0
14. November	'82	2264	662	236	0											
15. December	'82															
16. January	'83	744	573	4511	13200	3890	1095	1773	3027	840	99	17	0	0	0	0
17. February	'83	6857	8446	10474	3711	2524	10290	2990	4745	5770	2600	0	0	0		
18. March	'83															
19. April	'83															
20. May	'83	0														
21. June	'83	721	208	91	49	69	54	10	15	20	134	15	7	0	0	0
22. July	'83	4283	14610	14502	5027	17528	8346	2177	785	0						
23. August	'83	9392	0													
24. September	'83	3225	27584	23481	3187	33202	12414	17040	21339	7721	4599	3702	3333	1093	462	0

(Carpospores/g. fr. wt./day)

Month of Collection		Number of days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. October	'81	21219	465	3159	2568	3099	2319	620	1561	5224	5853	4043	5322	5822	1912	202
2. November	'81	9672	4754	3144	1869	3512	1691	619	1307	567	680	572	234	31	0	
3. December	'81	20948	9137	79	31	60	117	13	519	42	2	0				
4. January	'82	50639	23308	9396	22065	3234	490	285	545	42	4	0				
5. February	'82	2029	7129	3295	2804	1554	9767	18301	24042	8479	1758	8044	2921	816	886	1928
6. March	'82	86253	63952	25413	10419	15385	10688	2998	1551	843	769	1426	1108	1110	441	482
7. April	'82	55675	11673	4202	3890	3846	744	375	6788	1087	393	379	2278	638	1908	3293
8. May	'82	33784	4745	3118	8996	3124	10524	3624	1070	500	1000	636	320	249	176	610
9. June	'82	24475	5284	3701	1064	892	373	6565	3163	1239	1086	4471	930	102	3918	709
10. July	'82	35856	15081	5914	5073	360	647	991	823	4681	1237	420	2493	2106	1913	1763
11. August	'82	15887	1148	4012	5616	589	516	675	232	2129	2935	1987	340	367	1710	183
12. September	'82	2474	2322	1262	2031	879	1186	552	323	841	371	299	203	186	90	1150

(Contd..... 2.)

(Carpospores/g. fr. wt./day)

Month of Collection		Number of days														
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1. October	'81	66	159	87	1624	180	142	29	154	78	63	0				
2. November	'81	-	-													
3. December	'81	-	-													
4. January	'82	-	-													
5. February	'82	166	661	207	130	155	22	314	71	139	107	13	0			
6. March	'82	230	446	463	185	868	198	2433	28	21	49	10	41	21	0	
7. April	'82	0	-	-												
8. May	'82	696	4106	101	124	1098	7765	3279	608	466	211	104	94	90	44	64
9. June	'82	845	2434	80	168	570	53	13	139	99	19	101	60	85	27	10
10. July	'82	4614	2449	240	146	115	122	94	64	39	152	107	52	66	242	231
11. August	'82	331	123	97	89	65	82	181	362	388	90	129	81	77	23	0
12. September	'82	1236	634	813	483	417	697	609	377	523	145	0				

(Contd..... 3.)

(Carpospores/g. fr. wt./day)

Month of Collection	Number of days														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13. October '82	15735	8291	3803	1968	2219	1588	709	4867	2817	611	4550	447	3136	557	1056
14. November '82	36216	8729	7505	2650	6255	8449	5919	2906	961	7222	6104	600	9635	11463	3453
15. December '82	27230	15117	16770	386	5882	394	1529	1092	2601	6142	715	2802	2658	2240	939
16. January '83	57170	30481	11884	10413	15959	4587	1039	4114	988	601	825	574	1900	1137	753
17. February '83	83675	43977	42347	14327	14011	17000	11993	16705	18059	3417	2423	1407	5731	6325	1048
18. March '83	47227	20286	19851	30961	18526	8859	6272	5613	5835	9294	4429	4004	146	461	87
19. April '83	29127	9865	8001	1919	4178	10785	4889	7433	6134	2296	9829	11760	3069	3200	4146
20. May '83	38652	23489	10905	28089	11926	9253	7045	13064	10906	2978	554	334	2564	2181	13816
21. June '83	31349	14304	3533	6446	11624	7755	6497	6666	5518	9748	2824	4885	733	1620	1129
22. July '83	62854	20987	6309	19740	31189	15303	1494	4222	3049	4467	11450	6105	2785	569	14574
23. August '83	47631	26759	6161	20317	18479	9875	1341	6755	18425	15990	7992	24705	8637	15058	1012
24. September '83	41733	16955	5506	16425	13615	15995	17070	1448	16326	33355	20026	31904	4916	9197	18871

(Contd..... 4.)

Month of Collection		Number of days														
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
13. October	'82	1435	681	432	425	1728	475	157	112	122	290	129	102	153	101	68
14. November	'82	1847	6660	14292	6585	3457	10852	12549	5870	8443	2500	1959	599	143	0	
15. December	'82	984	3596	310	305	502	393	372	10355	5688	1058	521	353	0		
16. January	'83	3534	8314	4862	10284	2814	4477	3677	8068	15141	2465	1770	643	459	200	0
17. February	'83	1824	6658	4683	2273	1350	1375	4736	2237	5213	2308	506	187	0		
18. March	'83	53	72	0												
19. April	'83	9002	5548	2235	1075	28	9	0								
20. May	'83	5816	2274	5015	2407	1397	13392	2759	353	405	0					
21. June	'83	81	64	34	51	7571	2307	1648	1294	481	96	175	76	77	23	0
22. July	'83	9569	4010	11519	1350	705	5174	2246	19575	9847	6928	1917	500	344	0	
23. August	'83	1465	1122	1687	575	5856	1926	0								
24. September	'83	7301	1321	9530	5974	3075	9189	8901	1416	669	3862	4024	1146	1722	3992	2369

(Carpospores/g. fr. wt./day)

Month of Collection	Number of days										
	1	2	3	4	5	6	7	8	9	10	11
1. *August '82	130471	38132	12970	2451	2689	1037	1431	644	656	2344	514
2. September '82	9028	2951	1927	938	521	260	313	174	0		
3. October '82	86900	37664	1965	4683	1659	0					
4. November '82	80825	47069	23091	2114	981	6226	2172	2892	5183	4492	5440
5. December '82											
6. January '83	208935	49981	34003	22030	10391	22559	6923	2238	547	3297	2210
7. February '83	130326	61407	4798	1905	2681	3231	854	0			
8. March '83	110368	30788	21857	24683	5258	11585	1412	0			
9. April '83	105251	85201	68956	67514	108110	39378	12409	389	0		
10. May '83	169931	57265	82697	30719	55233	11947	44483	26922	987	0	
11. June '83	175969	72783	7250	14341	18606	4464	42278	10784	1115	2077	9298
12. July '83	304920	68474	65554	22696	2703	38261	176	0			
13. August '83	Cystocarpic plants not found										
14. September '83	225724	52961	42189	27801	59291	20562	22400	34778	43080	14723	49874

* October '81 to July '82 Cystocarpic plants not found.

(Contd..... 2.)

Carpospores shedding at different days in *Hypnea musciformis* collected from Pudumadam

(Carpospores/g. fr. wt./day)

Month of Collection	Number of days										
	12	13	14	15	16	17	18	19	20	21	22
1. August '82	835	888	686	199	79	58	0	-	-	-	-
2. September '82	-	-	-	-	-	-	-	-	-	-	-
3. October '82	-	-	-	-	-	-	-	-	-	-	-
4. November '82	914	188	0	-	-	-	-	-	-	-	-
5. December '82	-	-	-	-	-	-	-	-	-	-	-
6. January '83	2043	1402	2703	1276	647	184	3389	1047	133	89	0
7. February '83	-	-	-	-	-	-	-	-	-	-	-
8. March '83	-	-	-	-	-	-	-	-	-	-	-
9. April '83	-	-	-	-	-	-	-	-	-	-	-
10. May '83	-	-	-	-	-	-	-	-	-	-	-
11. June '83	19658	1391	0	-	-	-	-	-	-	-	-
12. July '83	-	-	-	-	-	-	-	-	-	-	-
13. August '83	-	-	-	-	-	-	-	-	-	-	-
14. September '83	20035	13369	15506	3164	128	0	-	-	-	-	-

(Carpospores/g. fr. wt./day)

Month of Collection		Number of days											
		1	2	3	4	5	6	7	8	9	10	11	12	13
1. October	'81	2779	35	0	0	0	0	-	-					
2. February	'82	31779	4549	1455	525	71	272	82	133	48	96	47	473	28
3. March	'82	23871	4402	9373	1971	1001	313	102	31	15	0			
4. April	'82	8389	6420	4424	1348	131	144	26	0					
5. May	'82	6936	2865	2031	773	60	224	108	118	516	435	48	104	60
6. July	'82	57076	49664	28470	1505	513	118	113	112	116	32	99	72	164
7. August	'82	71380	7582	6757	5577	1909	490	234	399	1252	2048	368	238	86
8. September	'82	9845	2591	687	729	285	397	59	319	255	293	132	196	165
9. October	'82	129910	42599	5342	2591	6111	1880	971	0					
10. November	'82	30917	19933	8621	2795	1604	2237	497	1076	8041	4506	14963	11654	4150

(Contd..... 2.)

(Carpospores/g. fr. wt./day)

Month of Collection		Number of days												
		14	15	16	17	18	19	20	21	22	23	24	25	26
1. October	'81	-	-	-	-	-	-	-						
2. February	'82	0	-	-	-	-	-							
3. March	'82	-	-	-	-	-	-							
4. April	'82	-	-	-	-	-	-							
5. May	'82	31	12	0	-	-	-							
6. July	'82	92	44	48	20	16	13	11	0					
7. August	'82	55	97	747	947	451	309	361	558	556	164	133	0	
8. September	'82	190	308	125	48	81	77	60	29	15	39	33	0	
9. October	'82	-	-	-	-	-	-							
10. November	'82	2099	1385	0	-	-	-							

(Contd..... 3.)

(Carpospores/g. fr. wt./day)

Month of Collection	Number of days												
	1	2	3	4	5	6	7	8	9	10	11	12	13
11. December '82	47650	11234	2319	957	9979	56027	18741	8993	712	110	58	54	363
12. January '83	98130	51345	5920	1695	3751	7150	5993	4214	3119	8813	1299	1180	269
13. February '83	73134	42517	18313	3385	745	906	164	960	341	763	315	271	166
14. March '83	67173	27394	18647	15587	11258	2766	824	48	0				
15. April '83	81059	37980	12316	2465	3147	366	8604	8959	6993	1028	4674	3670	351
16. May '83	72237	23703	10447	7832	10207	2815	5110	3348	8225	6376	5238	5343	4597
17. June '83	61594	24877	9936	4346	6522	3385	3575	6038	18204	6632	3051	1259	11164
18. July '83	49095	15498	5500	24247	10578	5003	4337	1408	3786	12393	5626	1429	4846
19. August '83	67843	21784	9104	23645	26472	25932	8138	3911	19601	12592	2414	18014	5493
20. September '83	41374	17708	5132	5969	10374	8788	1237	311	6319	1800	3109	1755	1095

(Contd..... 4.)

Carpospore output at different days in Hypnea musciformis collected from Kilakkarai

(Carpospores/g. fr. wt./day)

Month of Collection	Number of days												
	14	15	16	17	18	19	20	21	22	23	24	25	26
11. December '82	1012	270	563	189	427	91	168	82	18	15	0		
12. January '83	279	0	-	-	-	-							
13. February '83	57	0	0	0									
14. March '83	-	-	-	-									
15. April '83	257	0	0	0									
16. May '83	538	124	0	0									
17. June '83	161	0	0	0	0	0							
18. July '83	4304	1266	413	40	0	0	0						
19. August '83	14279	13429	4751	1484	4859	0	0	0					
20. September '83	952	3503	4854	4795	355	403	7116	1086	194	76	0		

during the period of this investigation (Tables 5-8). Plate (10) shows the photographs of tetraspores and carpospores of these four red algae.

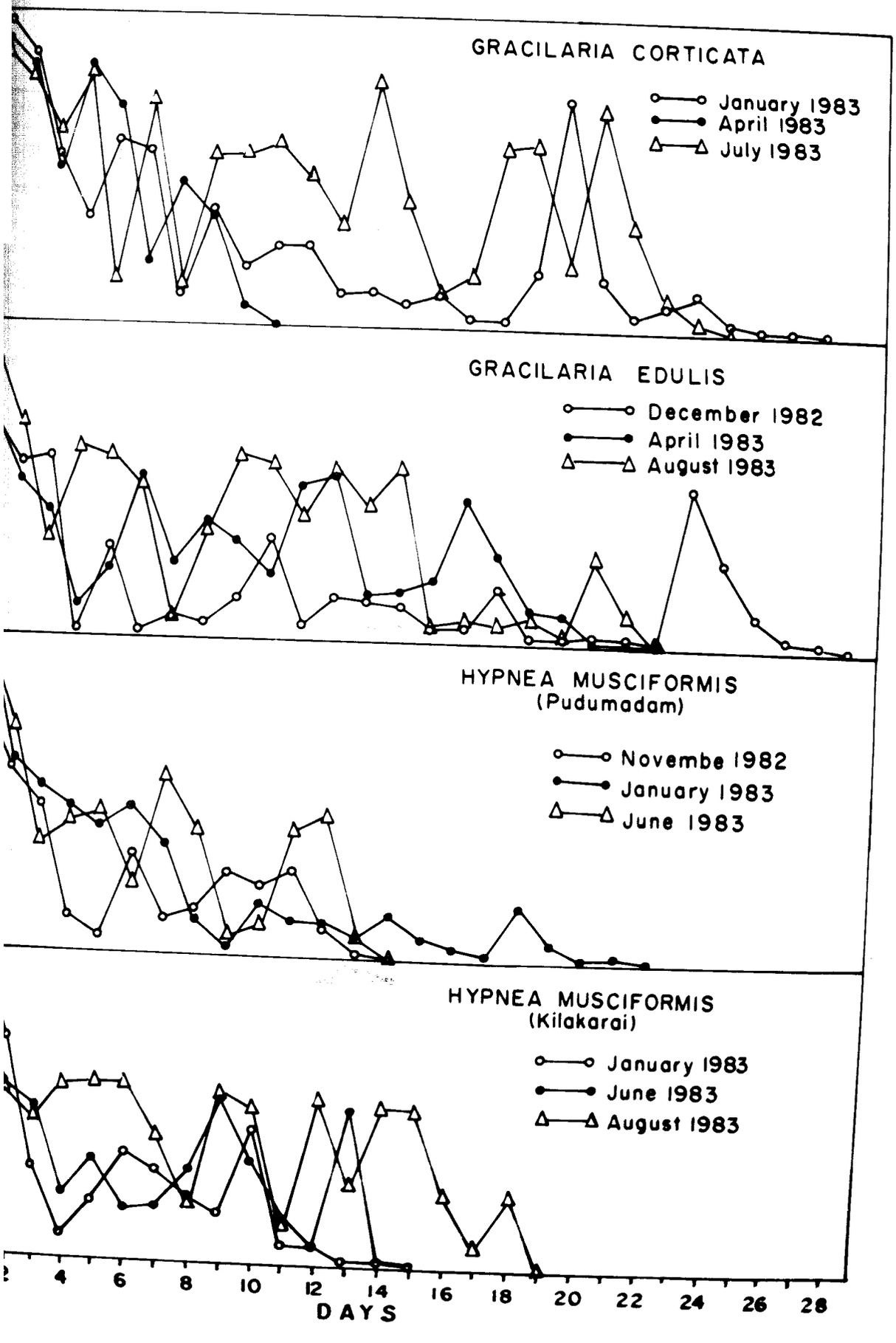
4.3 SEASONAL CHANGES IN SPORE OUTPUT

The total quantity of tetraspores and carpospores liberated at different days from plants collected during every month was used for estimating the monthly variation in spore production. The number of stichidia and tetraspores per gram fresh weight of the plant of Gelidiella acerosa from October 1981 to September 1983 are given in Fig. 2. The tetraspore and carpospore output for Gracilaria corticata are plotted in Fig. 2C,D and for Gracilaria edulis and Hypnea musciformis in Fig. 4.

In Gelidiella acerosa stichidia containing tetraspores were found in all months of the year without any seasonal variations in their abundance. However, maximum number of stichidia per gram fresh weight of the plant occurred between April and July 1983. During the period of this study, the number of stichidia varied from 13 to 418 per gram fresh weight of the plant (Fig. 2A). Figure 2B shows the monthly and yearly variations in tetraspore shelding of Gelidiella acerosa. Spore liberation occurred in all the months of the year. Though there was no regular trend in spore output, maximum shedding of tetraspores was observed

Figure No.3 Rhythmic liberation of carpospores in Gracilaria corticata (A), G. edulis (B) and Hypnea musciformis from Pudumadam (C) and Kilakkarai

GURE _ 3


GRACILARIA CORTICATA
January 1983
April 1983
July 1983
GRACILARIA EDULIS
December 1982
April 1983
August 1983
HYPNEA MUSCIFORMIS
(Pudumadam)
Novembe 1982
January 1983
June 1983
HYPNEA MUSCIFORMIS
(Kilakarai)
January 1983
June 1983
August 1983
4
6
8
10
12
14
16
18
20
22
24
26
28
DAYS

in the first year in the month of July and in the second year from April to September with a low value in July is shown in Fig. 2B. The tetraspore output ranged from 5,744 to 3,89,793 spores per gram fresh weight and there was no relationship between the number of stichidia and spores liberated from the plants collected in different months of the year in Gelidiella acerosa.

Shedding of tetraspores and carpospores in Gracilaria corticata were found in all months of the year and regular changes were not observed either in the output of tetraspores or carpospores (Fig. 2C and 2D). The tetraspore output varied from 8,181 to 92,277 and carpospores from 8,086 to 4,87,178 spores per gram fresh weight. In Gracilaria edulis also tetraspore and carpospore output occurred in all the months of the year without any marked seasonal fluctuations in the production of tetraspores and carpospores (Figs. 4A and 4B). The tetraspore output varied from 2,135 to 1,09,565 and carpospores from 28,652 to 3,27,833 numbers.

Data on tetraspore output was collected for all the months of the year for Hypnea musciformis occurring in the intertidal area at Pudumadam (Fig. 4C). Information on carpospore output was gathered only for 13 months from August 1982 to July 1983 and September 1983 for Hypnea musciformis also collected from Pudumadam and for 20 months

Figure No.4 Seasonal variation in the liberation of tetraspores (A) and carpospores (B) of Gracilaria edulis and tetraspores (C) and carpospores (D) of Hypnea muscif

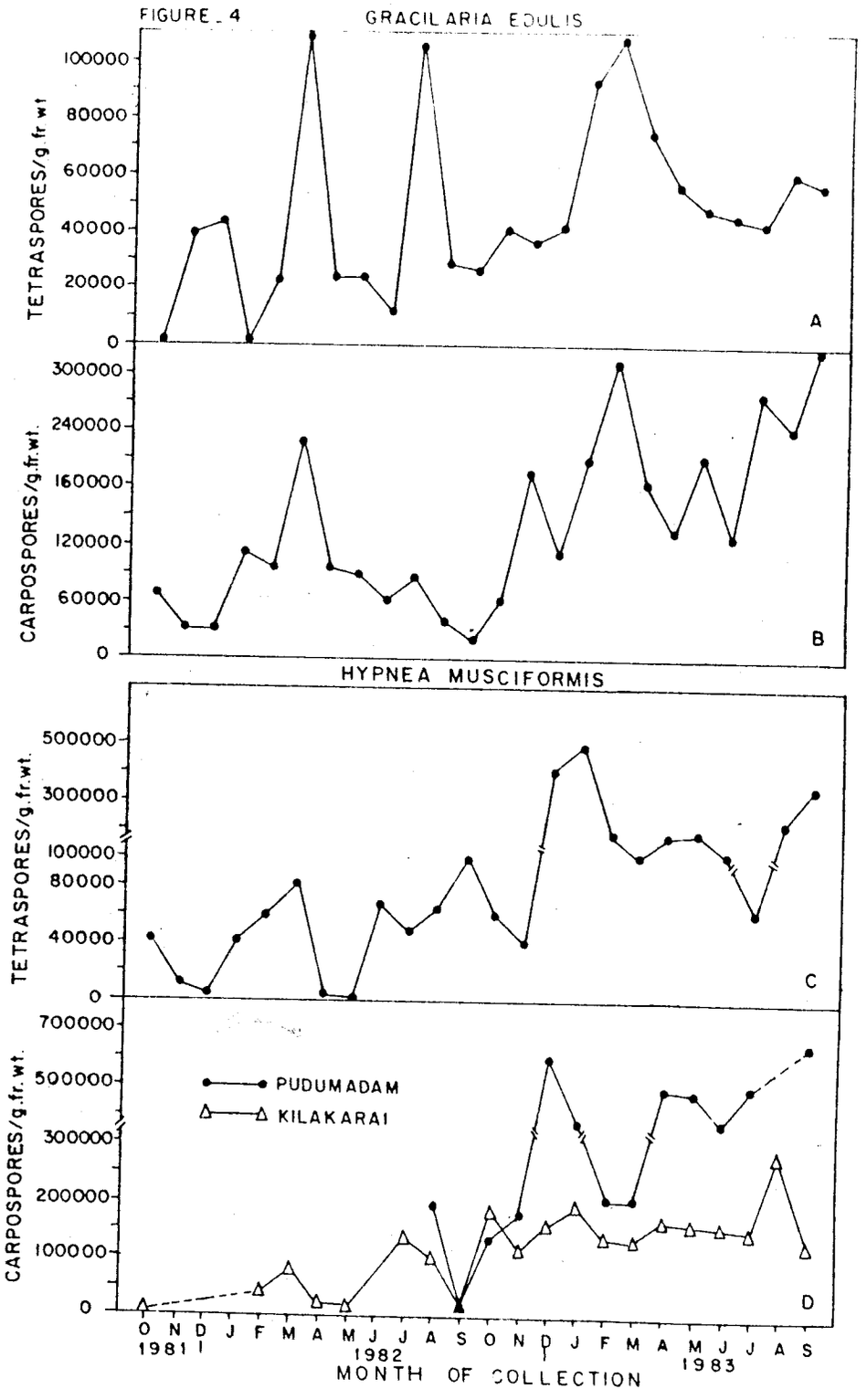


FIGURE_4
GRACILARIA EDULIS
TETRASPORES/g.fr.wt
CARPOSPORES/g.fr.wt.
A
B
HYPNEA MUSCIFORMIS
TETRASPORES/g.fr.wt.
CARPOSPORES/g.fr.wt.
C
D
PUDUMADAM
KILAKARAI
O N D J F M A M J J A S O N D J F M A M J J A S
1981
1982
1983
MONTH OF COLLECTION

for the same species collected from Kilakarai (Fig. 4d), since in the other months cystocarpic plants were not available in the field. Marked seasonal changes were not seen in the liberation of both tetraspores and carpospores. The tetraspore output varied from 2,662 to 5,04,953 spores per gram fresh weight per day. The carpospore output ranged from 16,112 to 6,46,385 and from 2,814 to 2,83,745 spores per gram fresh weight per day in Hypnea musciformis collected from Pudumadam and Kilakarai respectively.

4.4 DIURNAL PERIODICITY IN THE SPORE SHEDDING

To show the general trends in the daily periodicity in the liberation of tetraspores and carpospores in different months of the year, the mean values (expressed as percentage) of the experiments conducted in each month for 2 years from October 1981 to September 1983 with tetrasporophytes of Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis are plotted in Figs. 5 to 12. Data collected on seasonal changes in the diurnal periddicity in the shedding of carpospores for 2 years from October 1981 to September 1983 with Gracilaria corticata and G. edulis. For 1 year period from August 1982 to July 1983 with Hypnea musciformis collected from Pudumadam (Station II) and for 20 months for carpospore output in Hypnea musciformis collected from Kilakkarai (Station III) are plotted in Figs. 13-17.

Figure No.5 Diurnal periodicity in the shedding of tetraspores of Gelidiella acerosa collected from October 1981 to September 1982.

FIGURE_5. GELIDIELLA ACEROSA

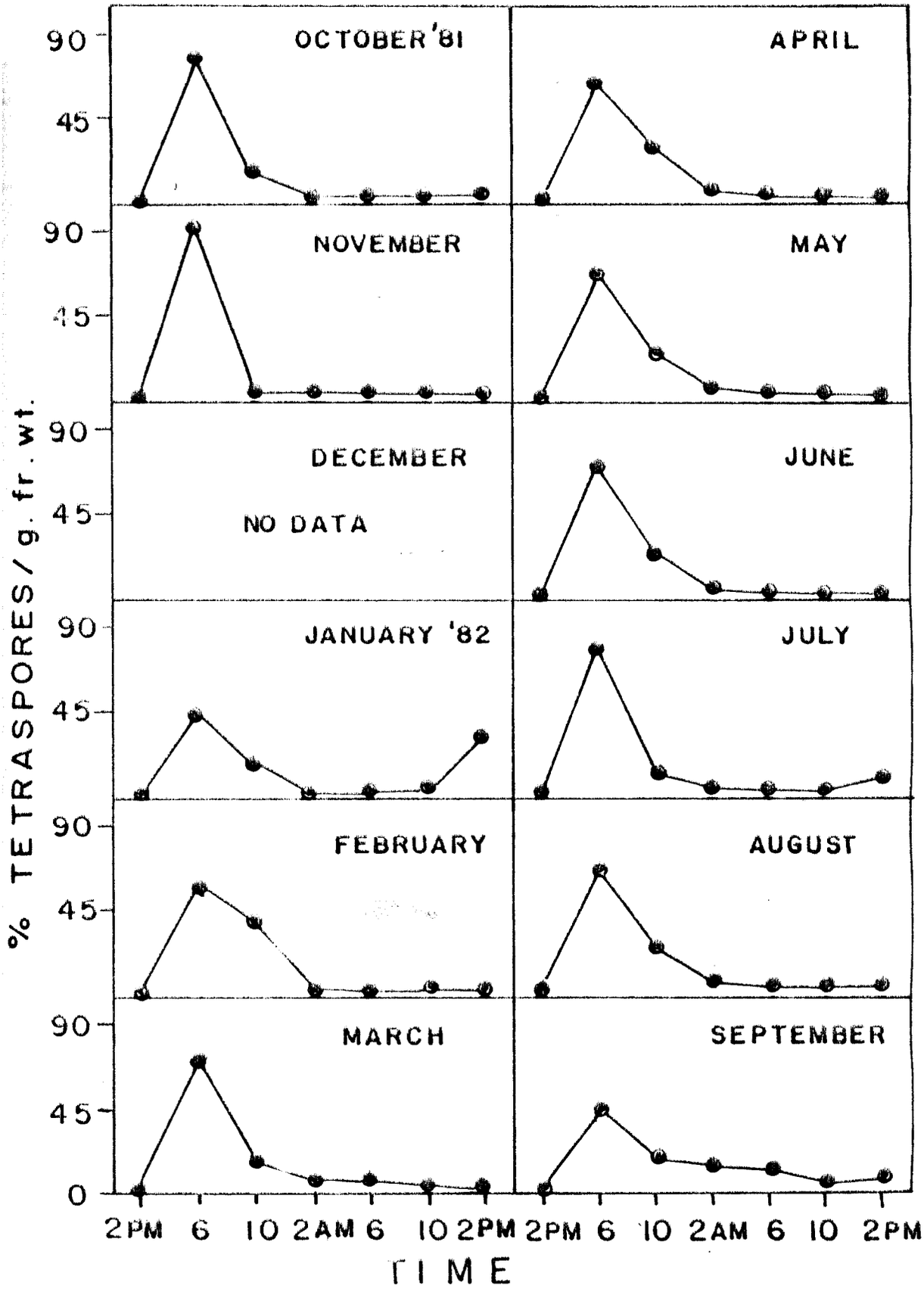


Figure No.6 Diurnal periodicity in the shedding of tetraspores of *Gelidiella acerosa* collected from October 1982 to September 1983.

FIGURE_6. GELIDIELLA ACEROSA

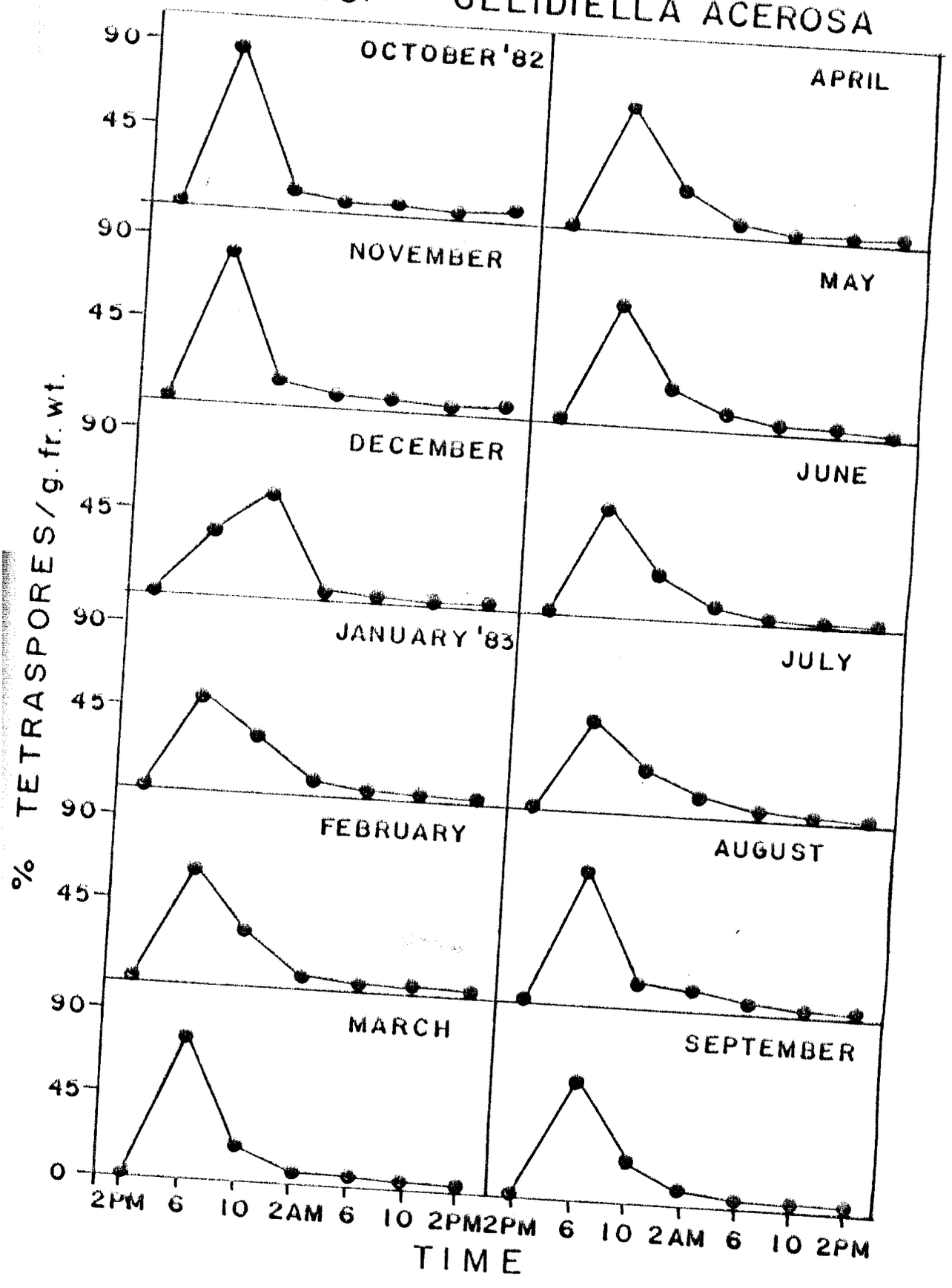


Figure No.7 Seasonal variation in the diurnal periodicity in the liberation of tetraspores of Gracilaria corticata collected from October 1981 to September 1982.

FIGURE 7. GRACILARIA CORTICATA

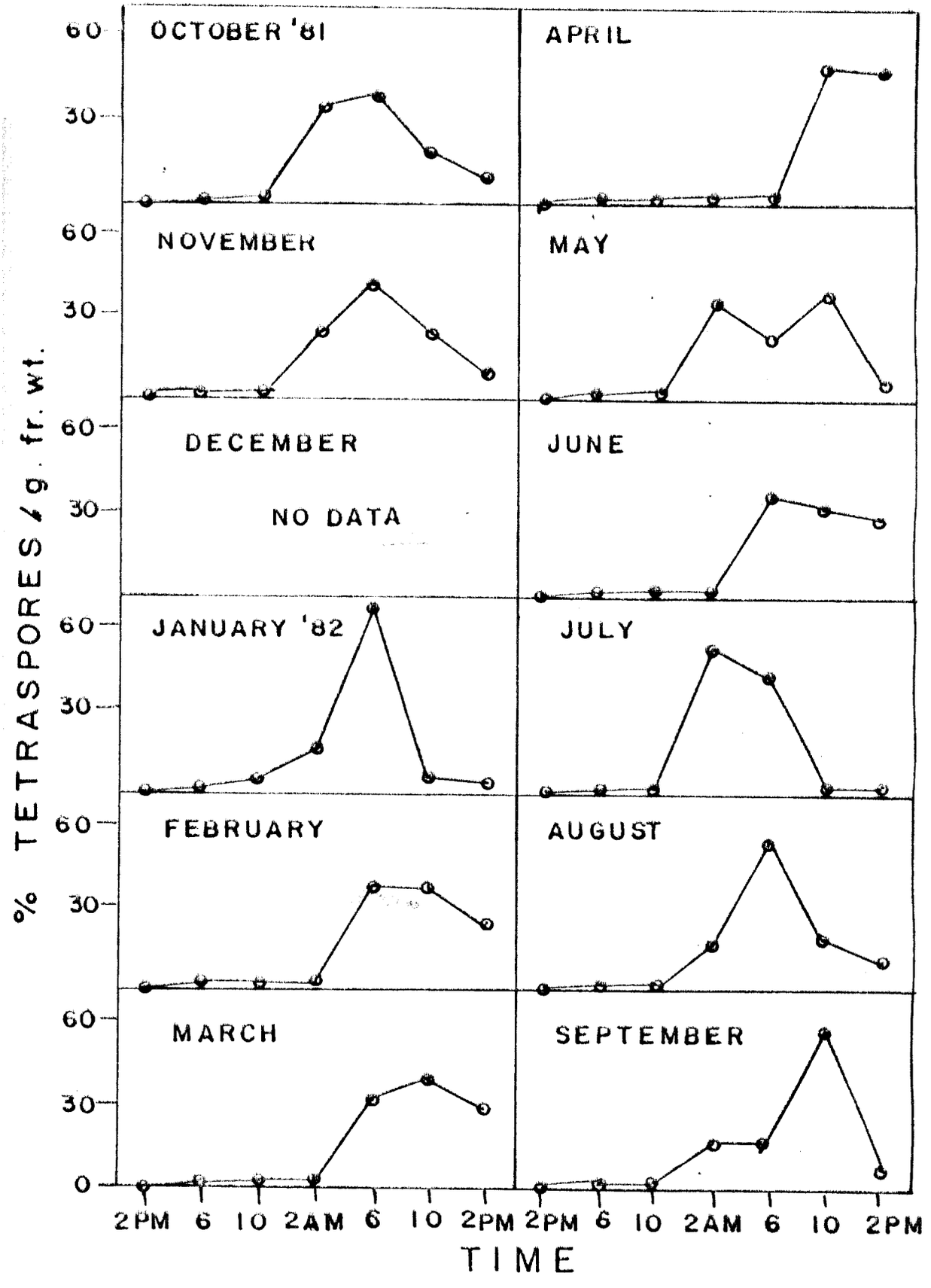


Figure No.8 Seasonal variation in the diurnal periodicity in the liberation of tetraspores of Gracilaria cortic collected from October 1982 to September 1983.

FIGURE_8. GRACILARIA CORTICATA

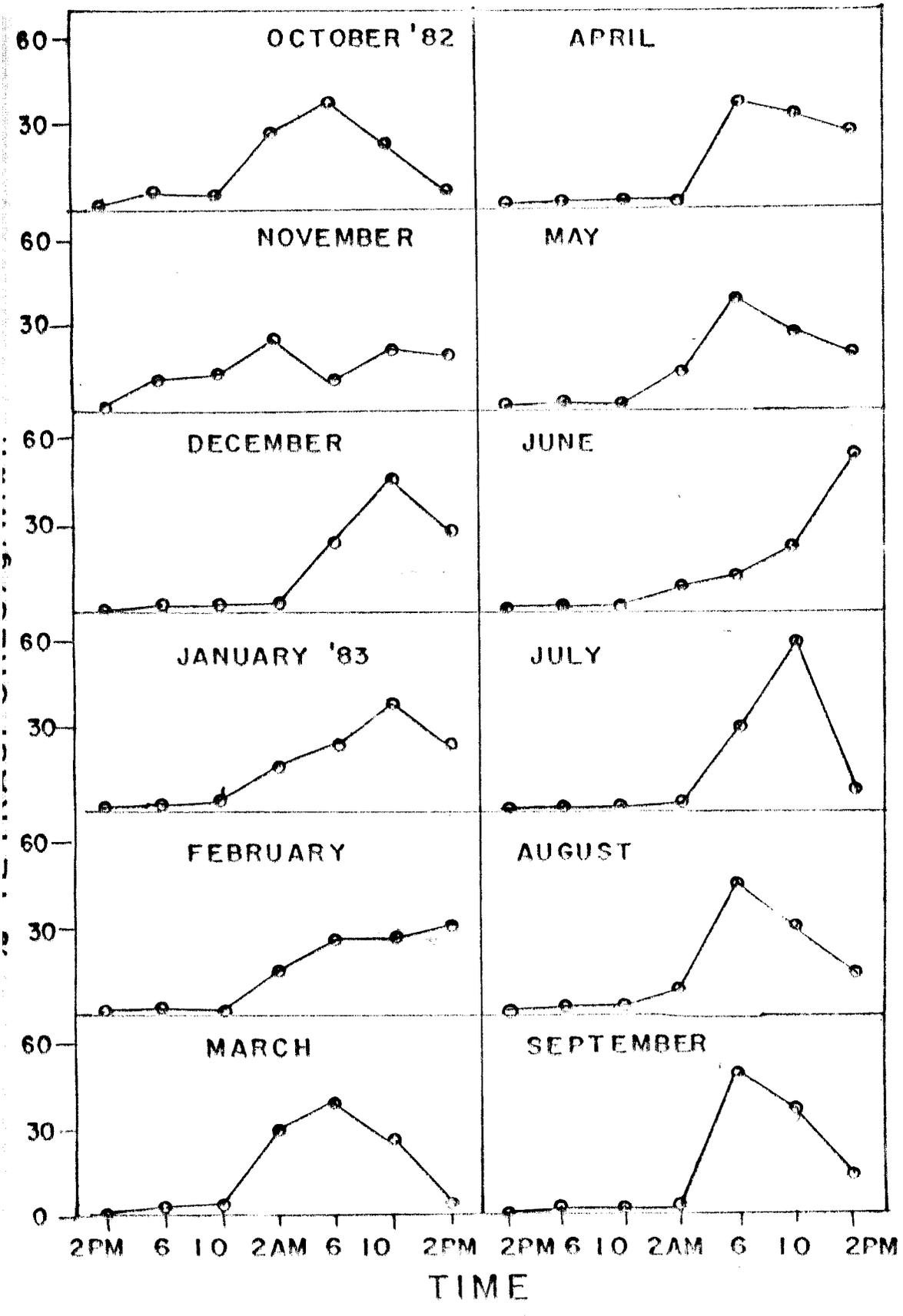


Figure No.9 Seasonal changes in the diurnal periodicity in the liberation of tetraspores of Gracilaria edulis collected from October 1981 to September 1982.

FIGURE. 9 GRACILARIA EDULIS

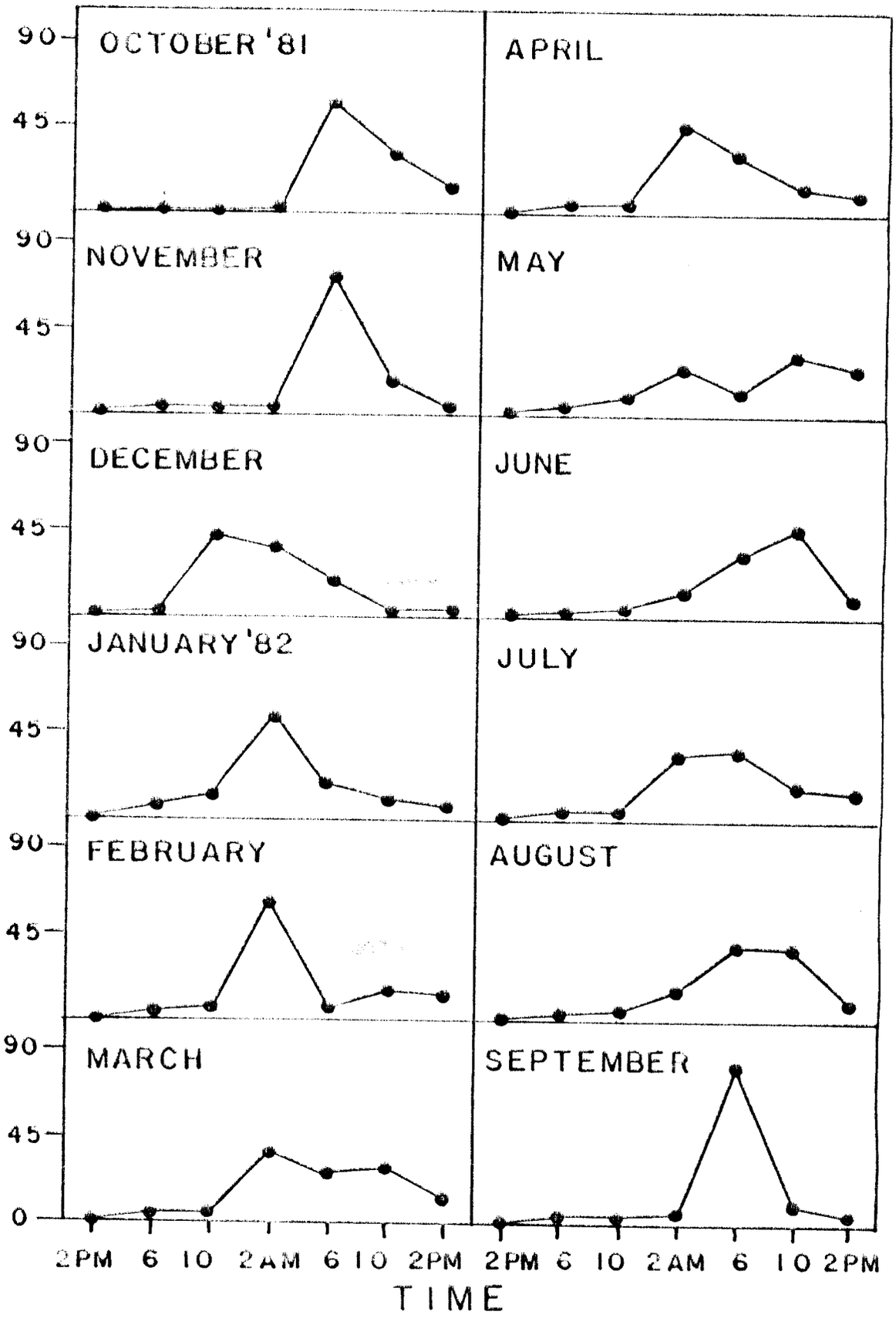


Figure No.10 Seasonal changes in the diurnal periodicity in the liberation of tetraspores of *Gracilaria edulis* collected from October 1982 to September 1983.

FIGURE.10. GRACILARIA EDULIS

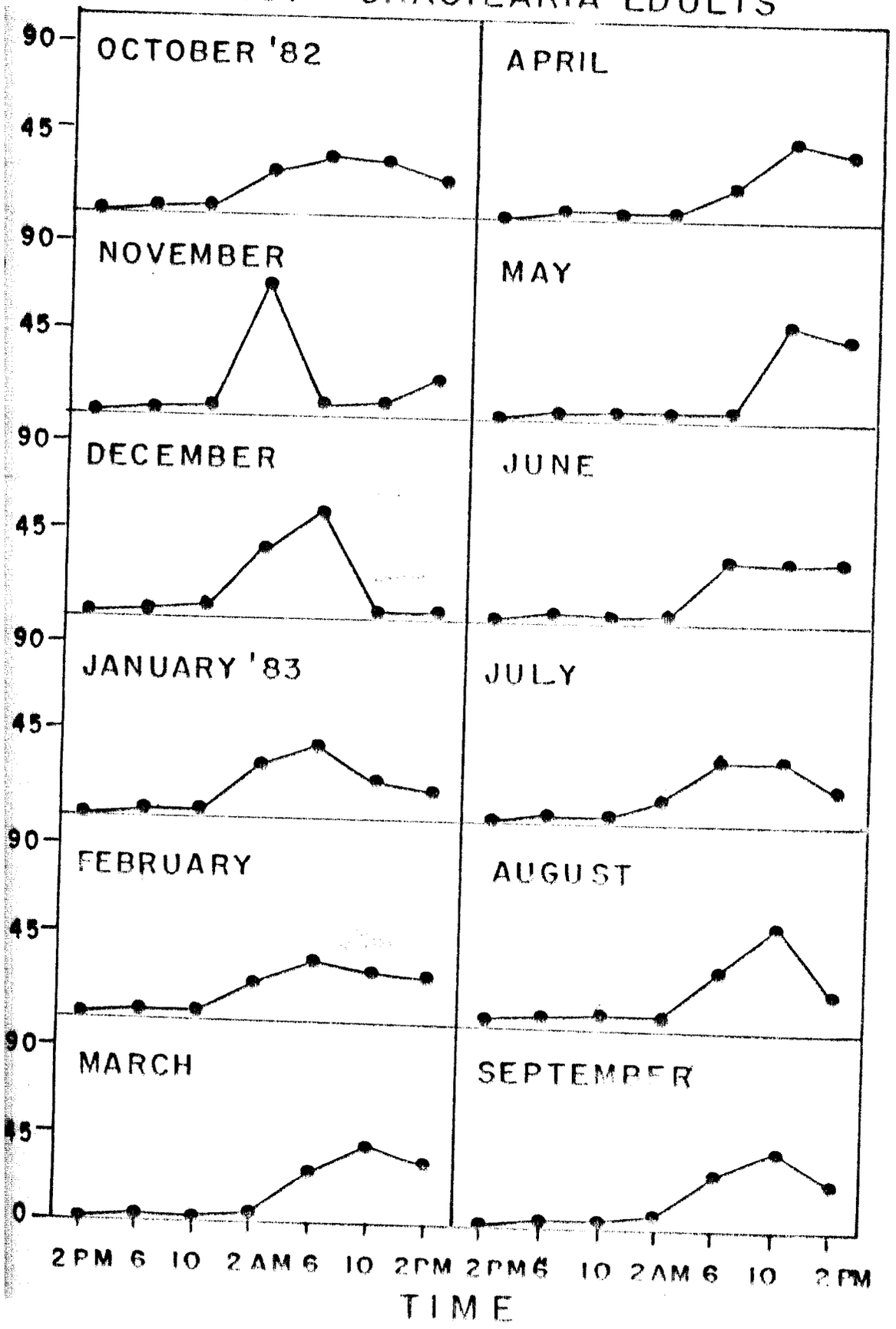


Figure No.11 Seasonal variation in the diurnal periodicity in the shedding of tetraspores of Hypnea musciformis collected from October 1981 to September 1982.

FIGURE 11. HYPNEA MUSCIFORMIS

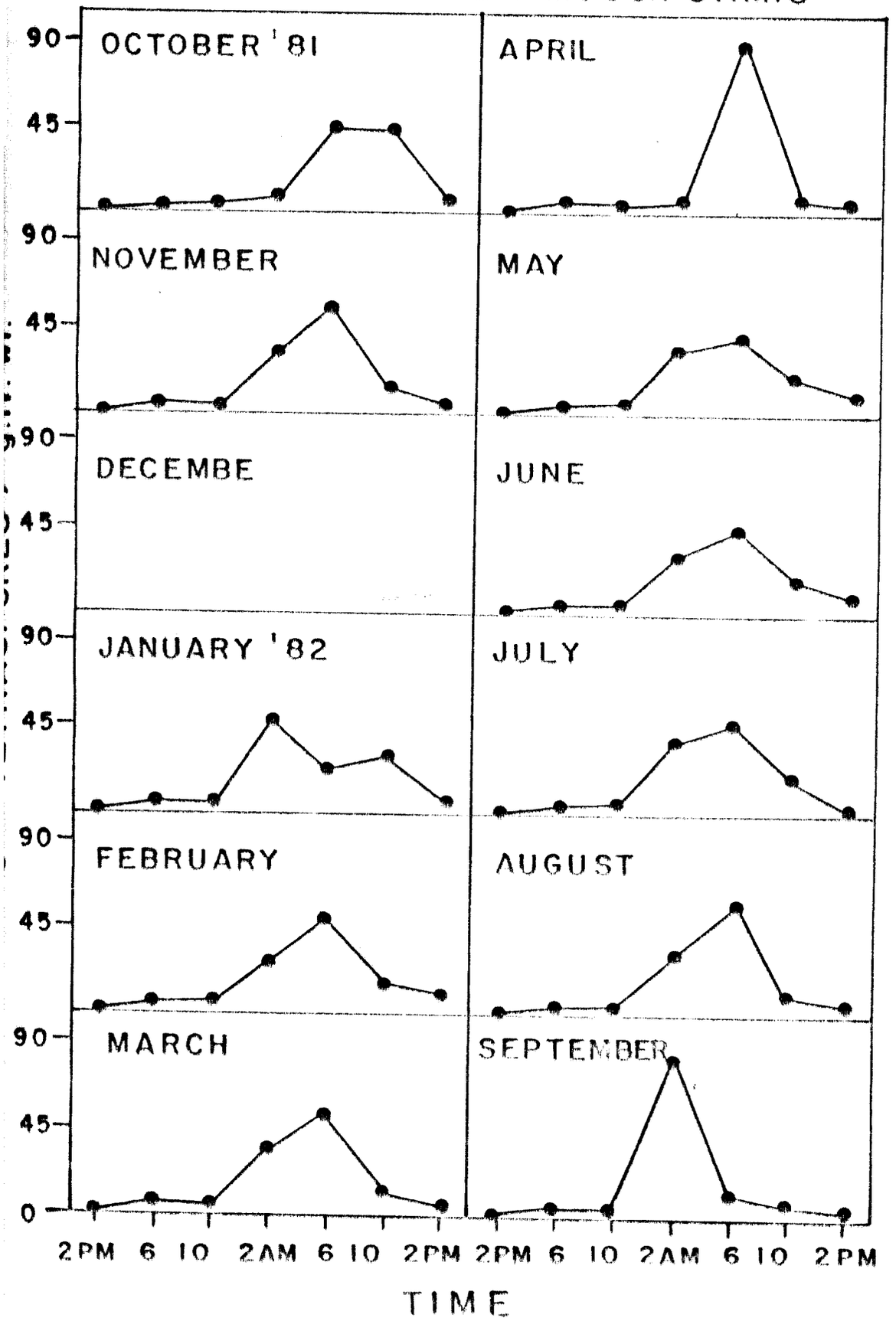
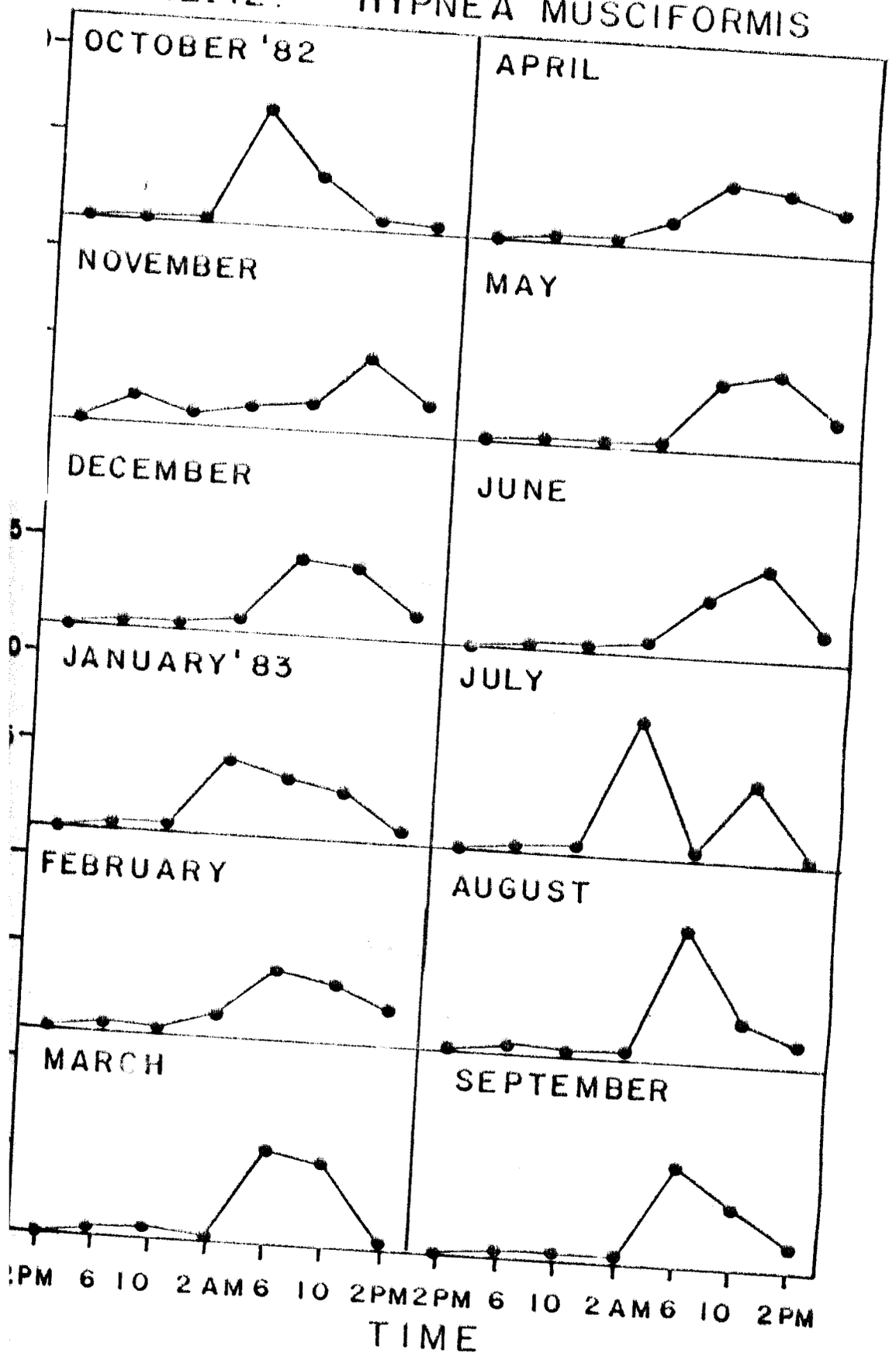


Figure No.12 Seasonal variation in the diurnal periodicity in the shedding of tetraspores of Hypnea musciformis collected from October 1982 to September 1983.

FIGURE. 12. HYPNEA MUSCIFORMIS



In Gelidiella acerosa except in December 1982, in all other months peak output of tetraspores was observed within the first hours after commencing the experiments i.e. between 2 PM and 6 PM. After 6 PM there was a sudden fall in the liberation of tetraspores and the percentage of spores liberated was minimum from 10 PM to 2 PM (Figs. 5 & 6). Sudden shedding of tetraspores with prominent peak at one period of the day was not seen in different months of the year in Gracilaria corticata, G. edulis and Hypnea musciformis (Fig. 7 to 12). In general, the quantity of spores liberated was more during the period of the day from 10 PM to 2 PM and minimum quantity of spore were liberated between 2 PM and 10 PM in all these three species of the order Gigartinales. Similar observations with maximum carpospore output from 10 PM to 2 PM were made from the cystocarpic plants of Gracilaria corticata and G. edulis (Figs. 13 to 16). But in Hypnea musciformis maximum liberation of carpospores occurred either from 10 PM to 2 AM or from 2 AM to 6 AM during the one year period from August 1982 to July 1983 collected from Pudumadam. The same was also observed for 2 years in the carpospore output of Hypnea musciformis collected from Kilakarai. The quantity of carpospores liberated between 2 PM and 10 PM in Gracilaria corticata, G. edulis and Hypnea musciformis was less (Figs. 13 to 17) as observed in the tetraspore output of these three species.

Figure No.13 Diurnal periodicity in the carpospor output of Gracilaria corticata colle from October 1981 to September 1982.

FIGURE. 13. GRACILARIA CORTICATA

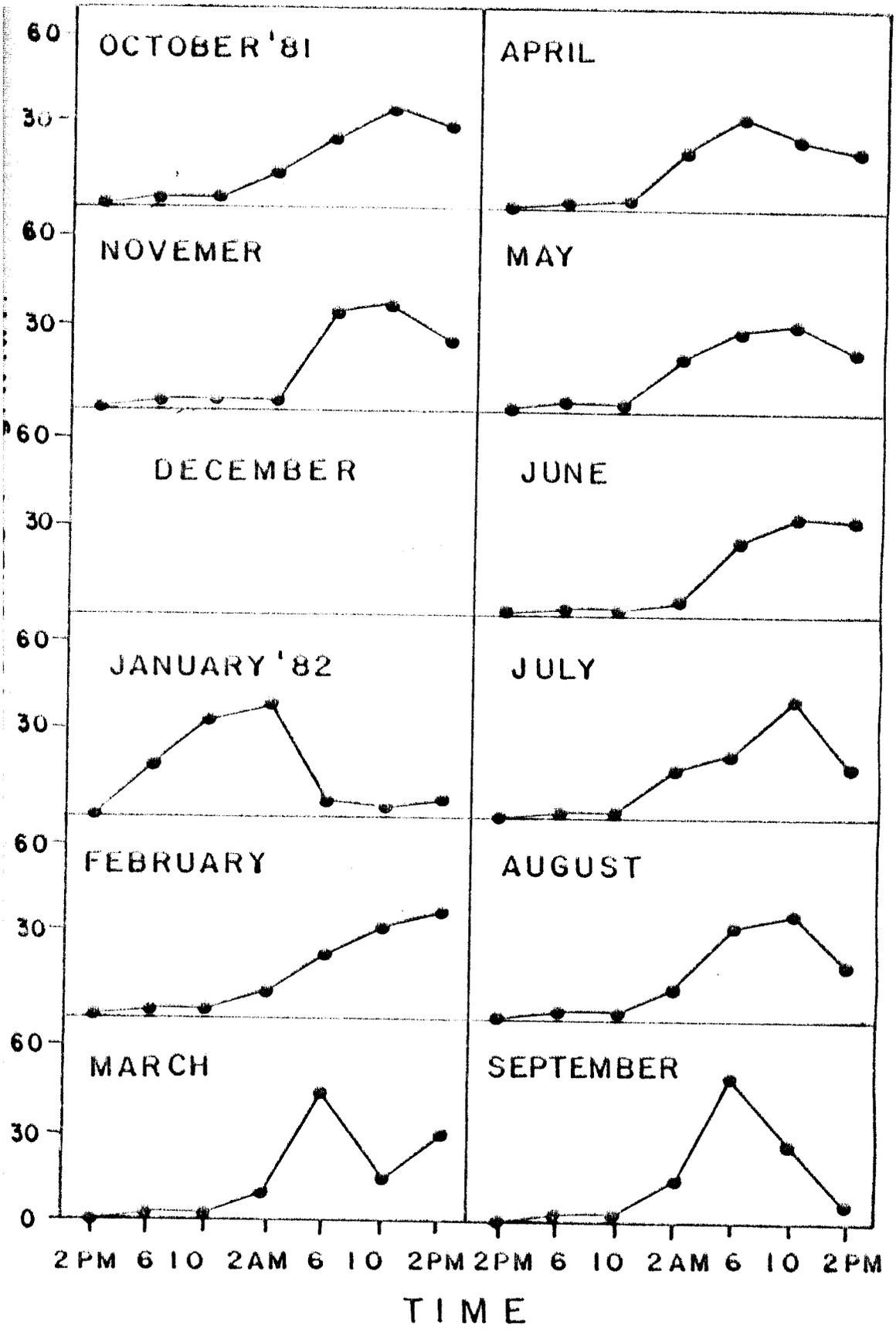


Figure No.14 Diurnal periodicity in carpospore output of Gracilaria corticata collected from October 1981 to September 1982.

FIGURE.14. GRACILARIA CORTICATA

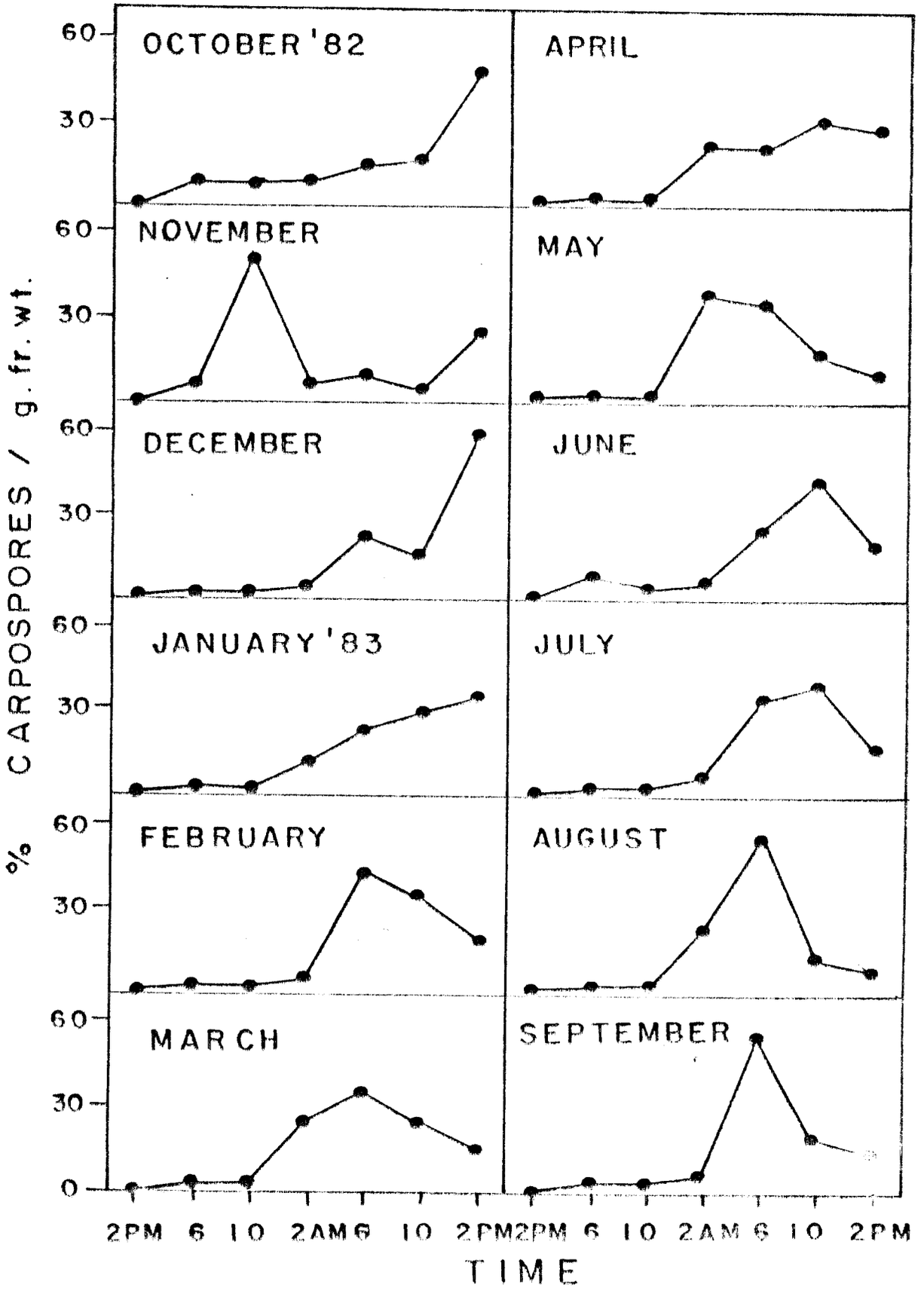


Figure No.15 Diurnal periodicity in the shedding of carpospore of *Gracilaria edulis* collected from October 1981 to September 1982.

FIGURE 15. GRACILARIA EDULIS

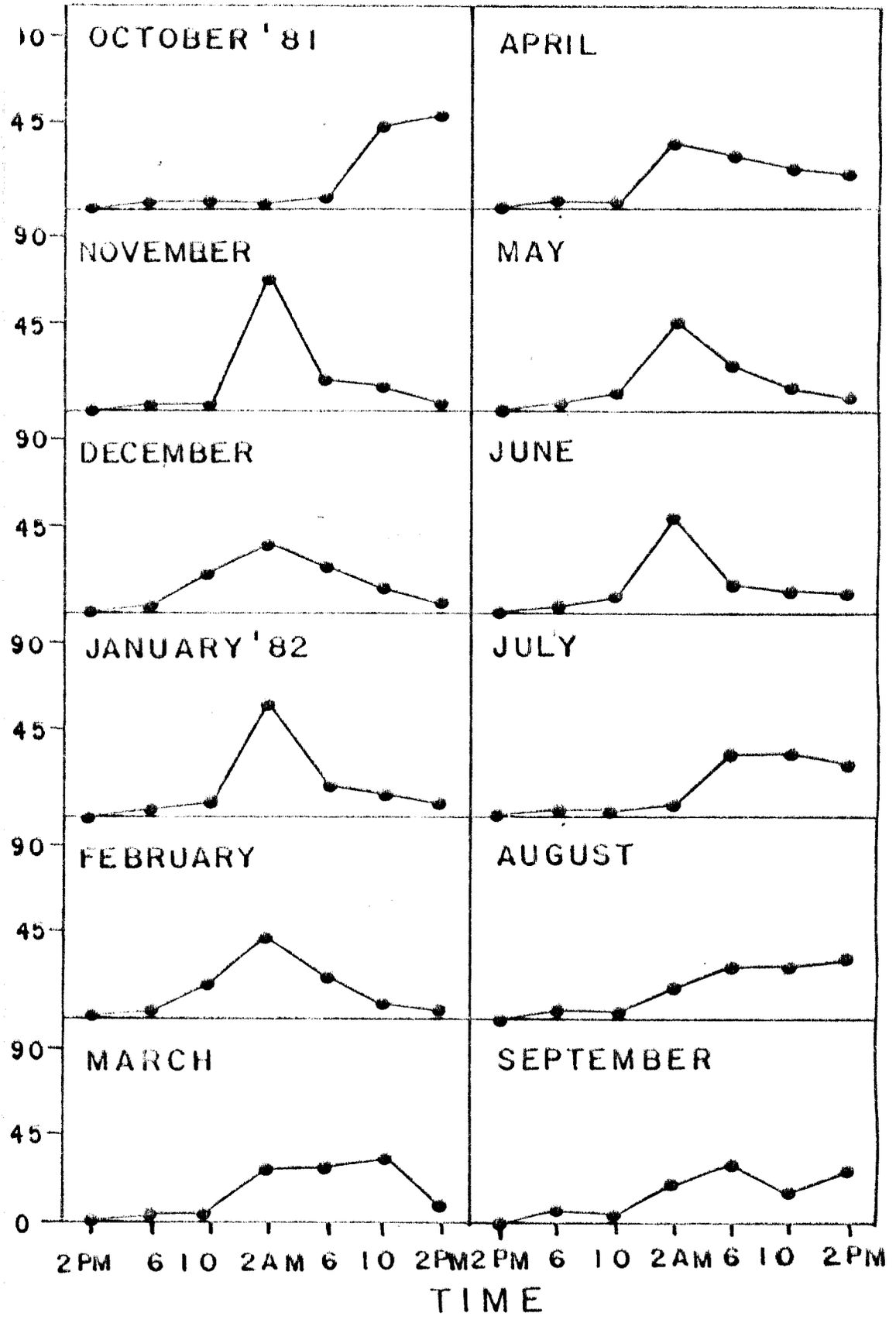
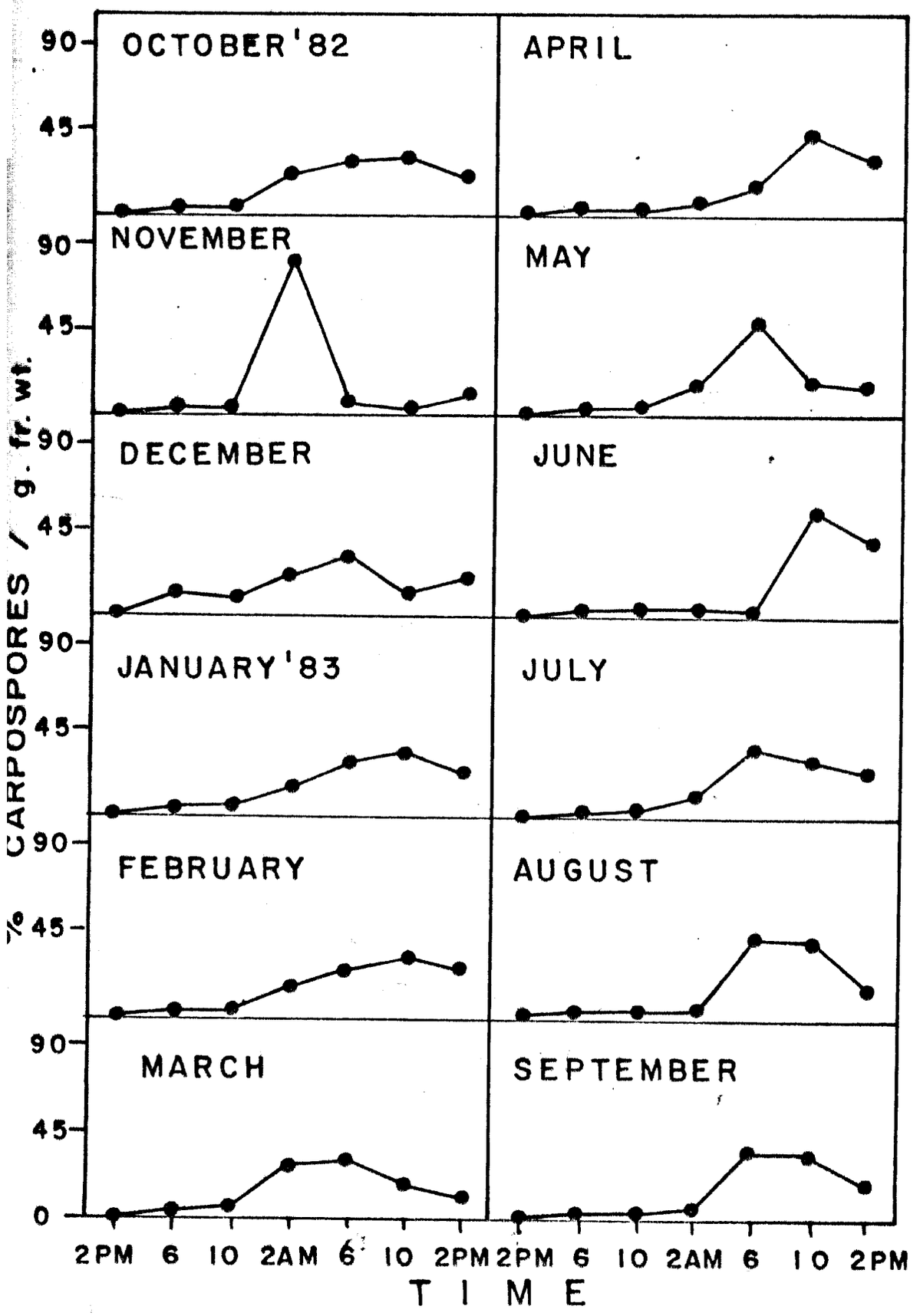


Figure No.16 Diurnal periodicity in the shedding of carpospores of Gracilaria edulis collected from October 1982 to September 1983.

FIGURE 16. GRACILARIA EDULIS



EFFECTS OF SELECTED ENVIRONMENTAL FACTORS ON SPORE SHEDDING

Results obtained on the effects of environmental factors such as exposure to air and desiccation, salinity, light and temperature on tetraspore liberation in *Gelidiella acerosa* and tetraspore and carpospore output in *Gracilaria corticata*, *G. edulis* and *Hypnea musciformis* are given below:

4.5.1 EXPOSURE TO AIR OR DESICCATION

This experiment was conducted with a view to study the effect of exposure during low tides and the resultant desiccation of plants on spore production and also to understand the spore release from plants occurring in shaded areas in the field. Changes observed in the release of spores from *Gelidiella acerosa*, *Gracilaria corticata*, *G. edulis* and *Hypnea musciformis* in the controls (0 minute exposure) and at different periods of exposure to air in the room (Temp. 28.5 to 30.7 °C and R.H. 52 % to 87 %) are shown in Figs. 18 to 21.

In the experiments conducted with tetrasporic thalli of *Gelidiella acerosa* exposing them to air in shade in the room at intervals of 15 minutes upto 120 minutes, sporulation was seen upto 105 minutes. Maximum output of tetraspores was found in control i.e. in fronds submerged for 24 hours and the number of spores liberated decreased

Figure No.18 Effect of desiccation on the tetraspor output in Gelidiella acerosa.

FIGURE 18. GELIDIELLA ACEROSA

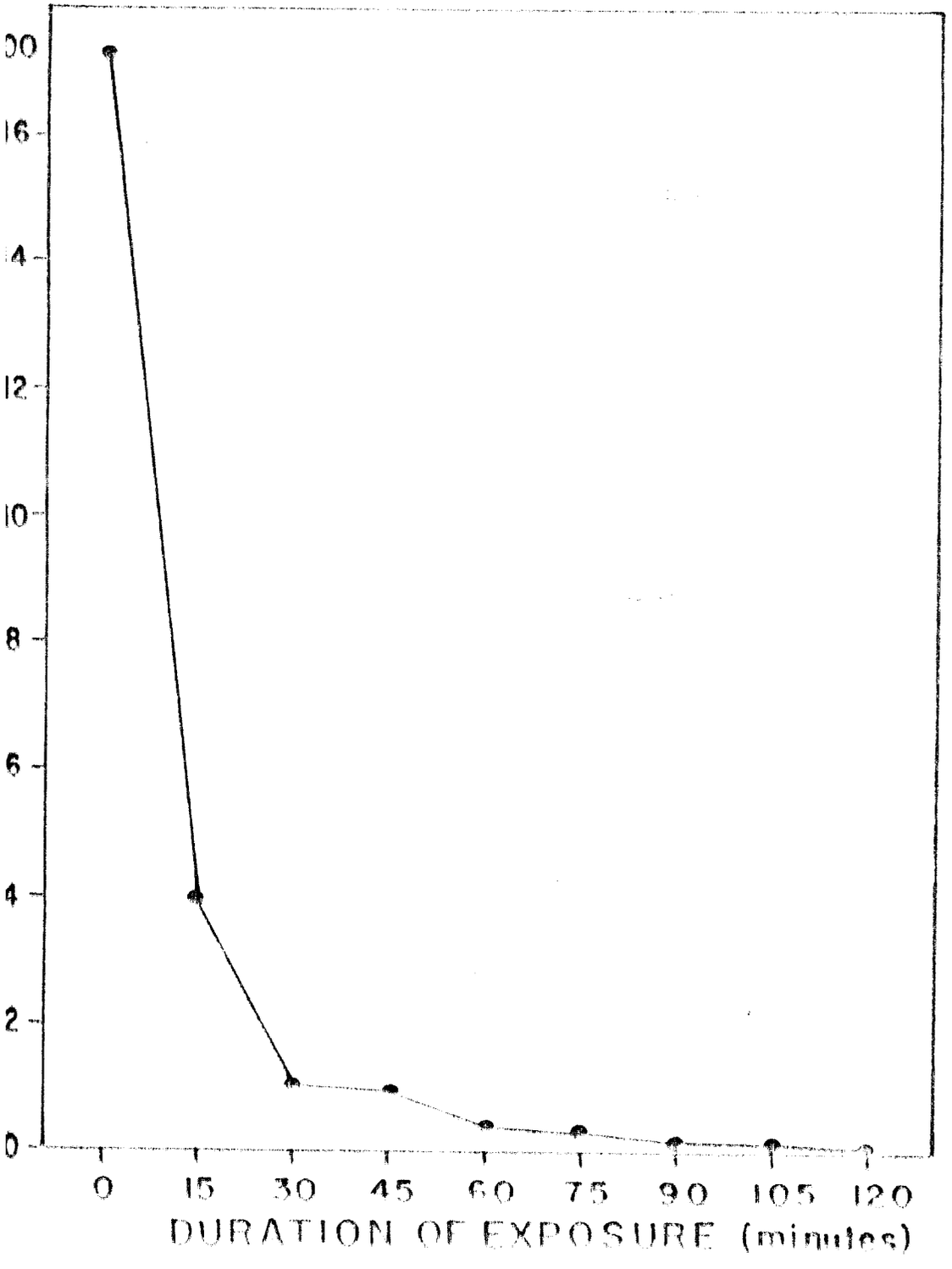


Figure No.19 Effect of desiccation on the liberatio of tetraspores and carpospores in Gracilaria corticata.

FIGURE_19. GRACILARIA CORTICATA

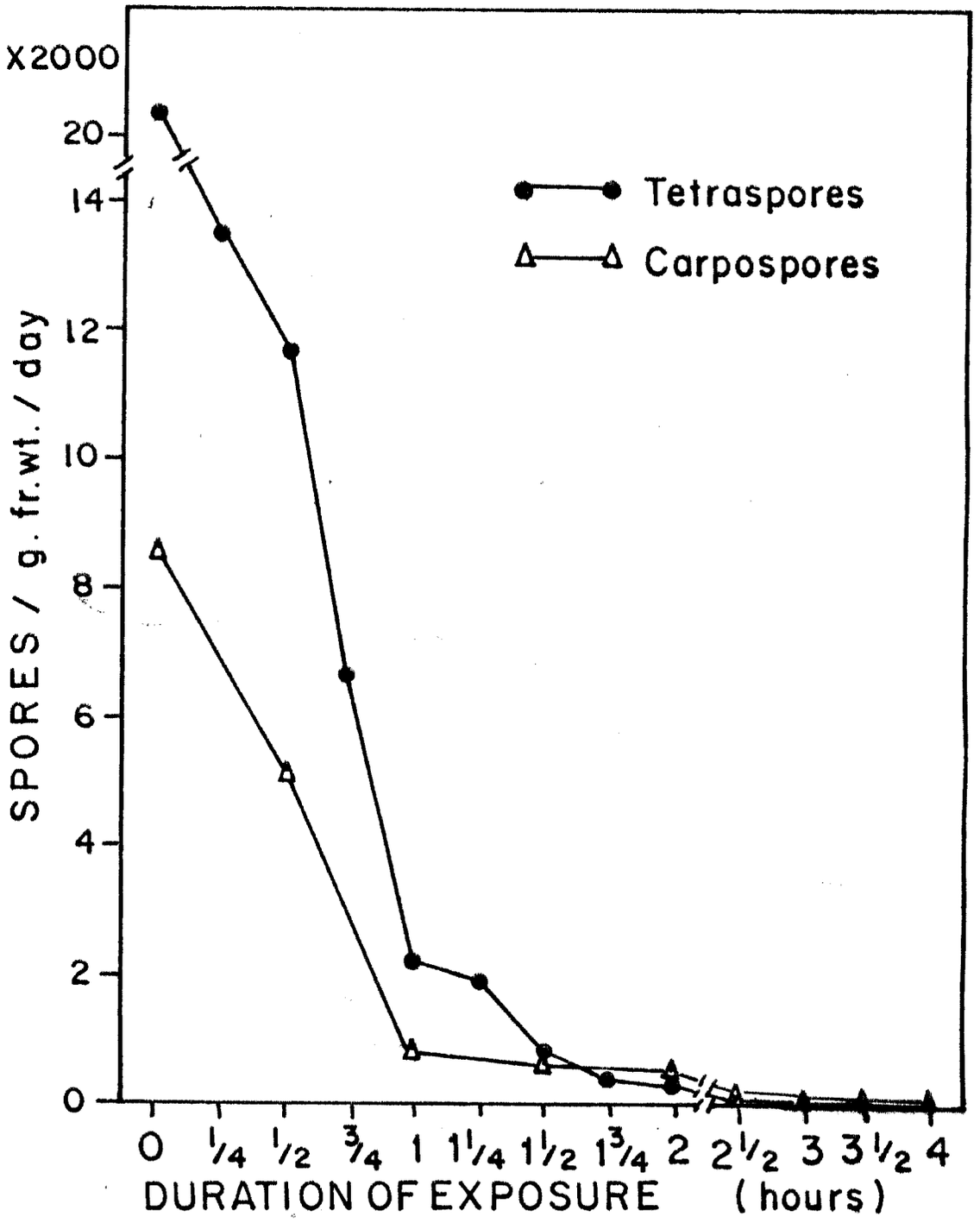


Figure No.20 Effect of desiccation on the liberation of tetraspores and carpospores in Gracilaria edulis.

FIGURE 20. GRACILARIA EDULIS

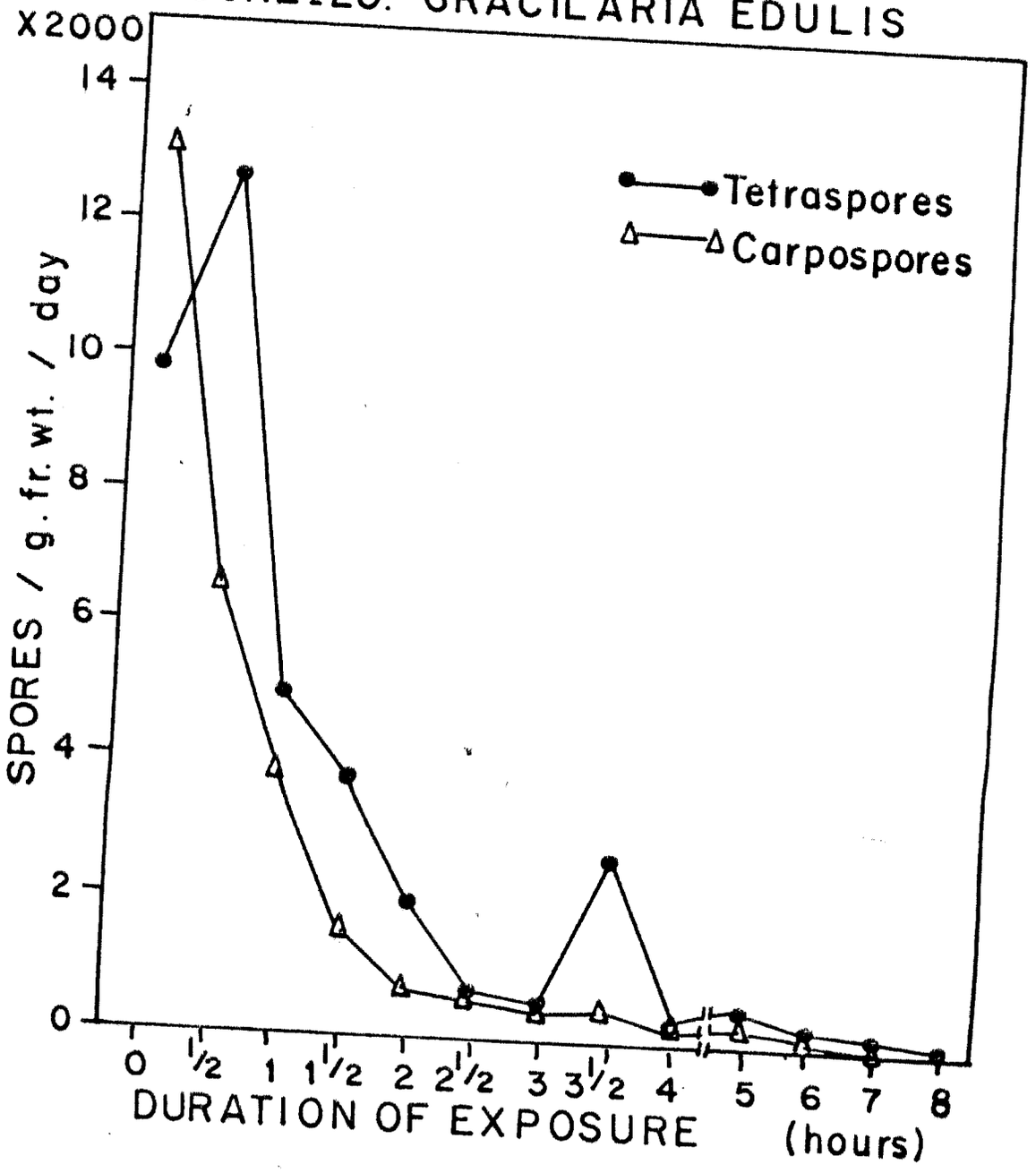
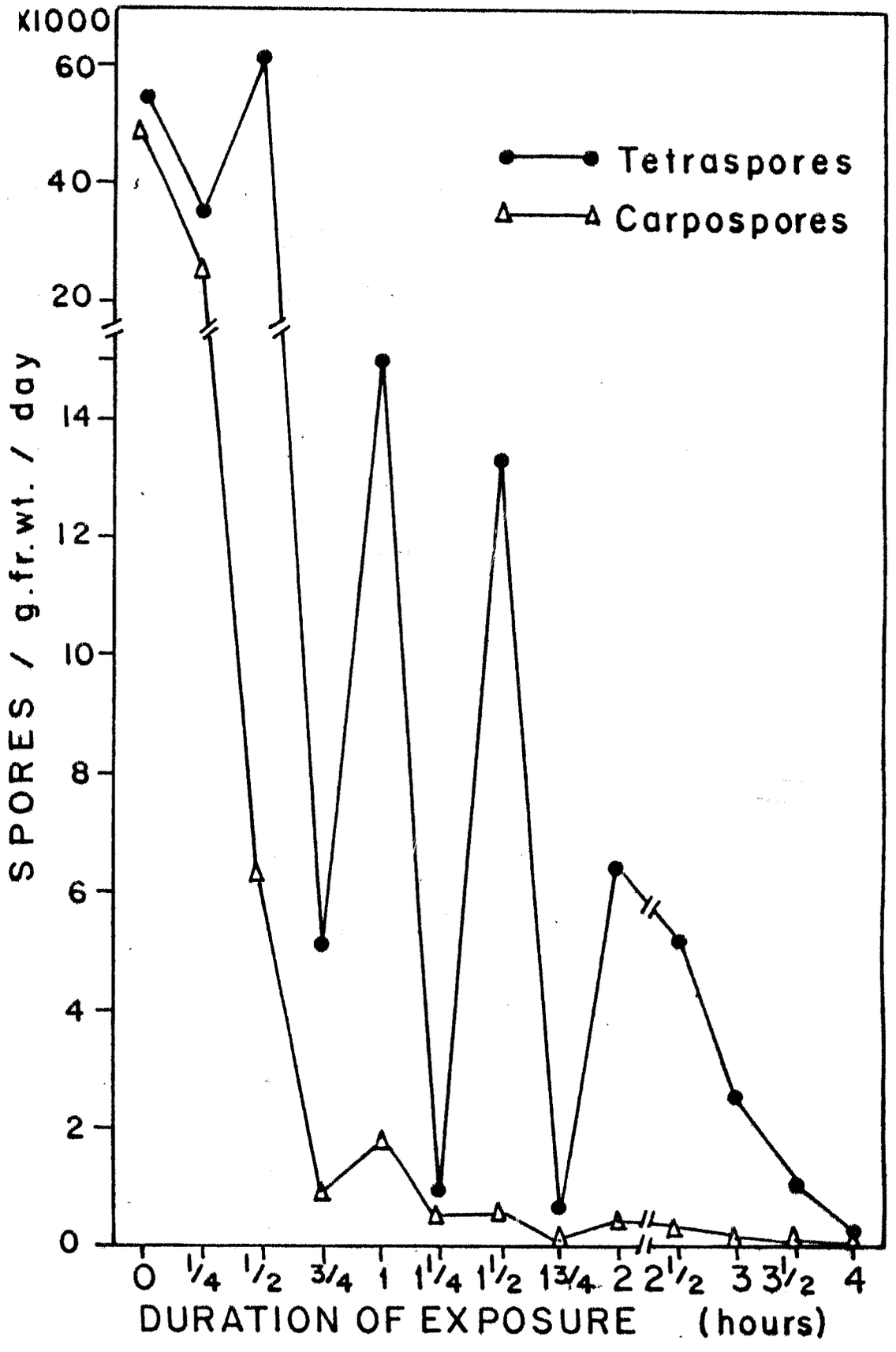


Figure No.21 Effect of desiccation on the shedding of tetraspores and carpospores in Hypnea musciformis.

FIGURE-21. HYPNEA MUSCIFORMIS



with increase in the duration of drying of plants at room temperature. The spore output declined rapidly in 15 minutes exposure and thereafter gradual decrease in the liberation of spores was observed in exposure of upto 105 minutes (Fig. 18). In the experiments conducted with tetrasporophytes and carposporophytes of Gracilaria corticata exposing them to air at ¼ and ½ hr intervals upto 4 hours, tetraspore output was found upto 4 hours and carpospore output upto 3½ hours. As observed in the liberation of tetraspores in Gelidiella acerosa, maximum quantity of tetraspores and carpospores were released in 0 minutes exposure and the spore output decreased gradually from ¼ hr exposure onwards (Fig. 19).

In the asexual and female plants of Gracilaria edulis exposed to air at ½ and 1 hour intervals upto 8 hours, shedding of tetraspores was seen upto 8 hours and carpospores upto 6 hours. The quantity of tetraspores liberated from 15 minutes exposed thalli was found to be more than control. From 1 hour exposure there is gradual decrease in spore discharge though there is slight increase in the release of tetraspores from 3½ hours exposed plants over 2, 2½ and 3 hr exposed plants. But maximum quantity of carpospore output in Gracilaria edulis was found in control with gradual decrease with increase in

the duration of exposure (Fig. 20) as observed in the tetraspore and carpospore release of Gracilaria corticata. In the tetrasporic and cystocarpic fronds of Hypnea musciformis exposed to air at ¼ and ½ hour intervals upto 4 hours, tetraspore liberation was seen upto 4 hours. The quantity of tetraspores released from the thalli exposed at different time intervals varied very much without showing any trend in the spore release. But maximum liberation of carpospores occurred in control with gradual decline except at hour exposure (Fig. 21).

4.5.2 SALINITY

Effects of salinity on spore output in Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis are shown in Figs. 22 to 25 respectively. Spore output varied markedly in different salinities of sea water tested from 0 o/oo (0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 o/oo). In all the four algae, release of spores occurred from 0 o/oo to 90 o/oo and there was no sporulation at 100 o/oo. Peak spore output of tetraspores was found at 40 o/oo in Gelidiella acerosa and at 30 o/oo in Gracilaria corticata, G. edulis and Hypnea musciformis. Though peak spore output occurred at these two salinities, the quantities of spore liberated at 20 o/oo and 50 o/oo in the four algae were also more than compared with the release of spores in other salinities.

Figure No.22 Effect of salinity on the tetraspore output in Gelidiella acerosa.

FIGURE.22. GELIDIELLA ACEROSA

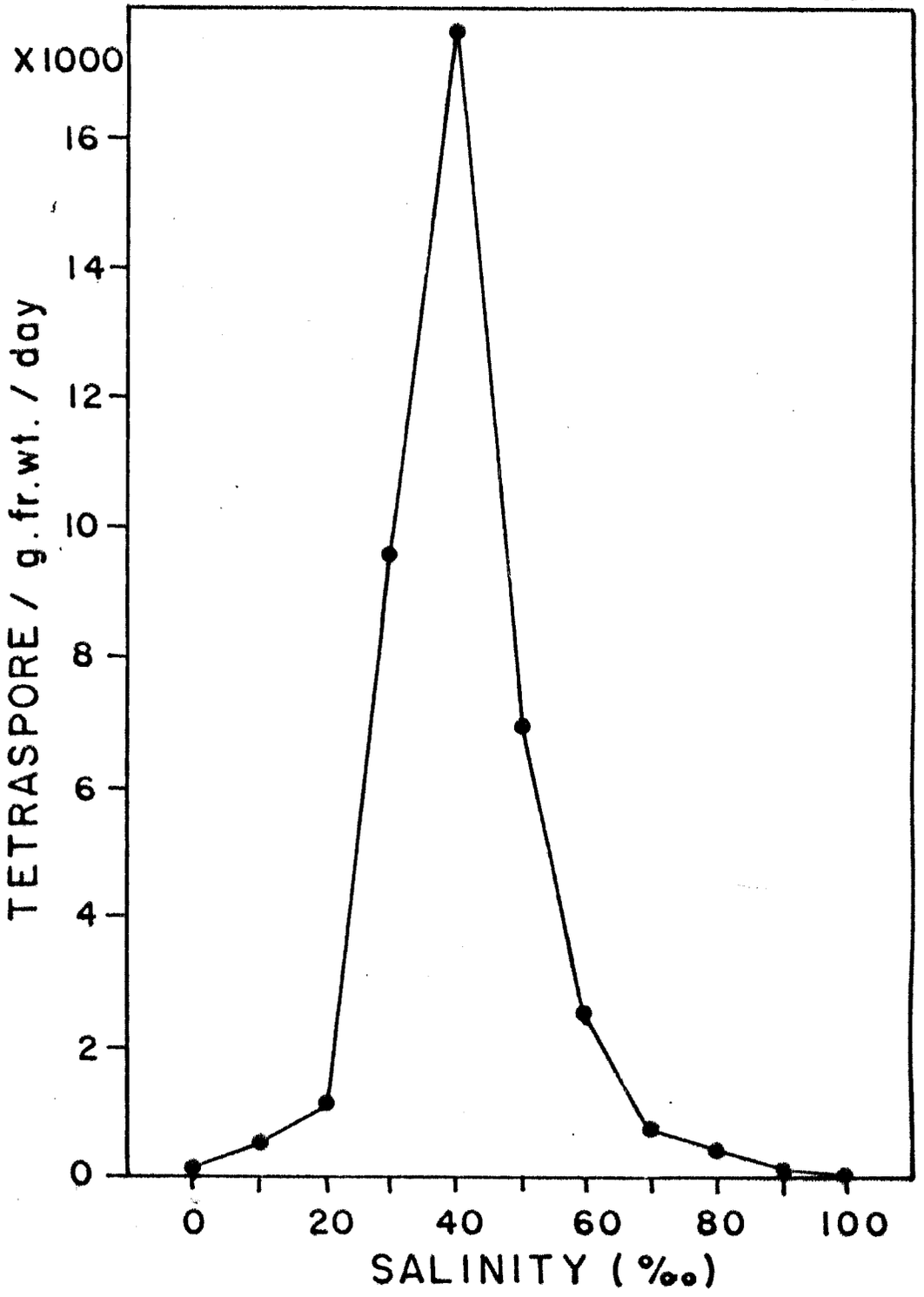


Figure No.23 Effect of salinity on the tetraspore carpospore liberation in *Gracilaria corticata*.

FIGURE. 23. GRACILARIA CORTICATA

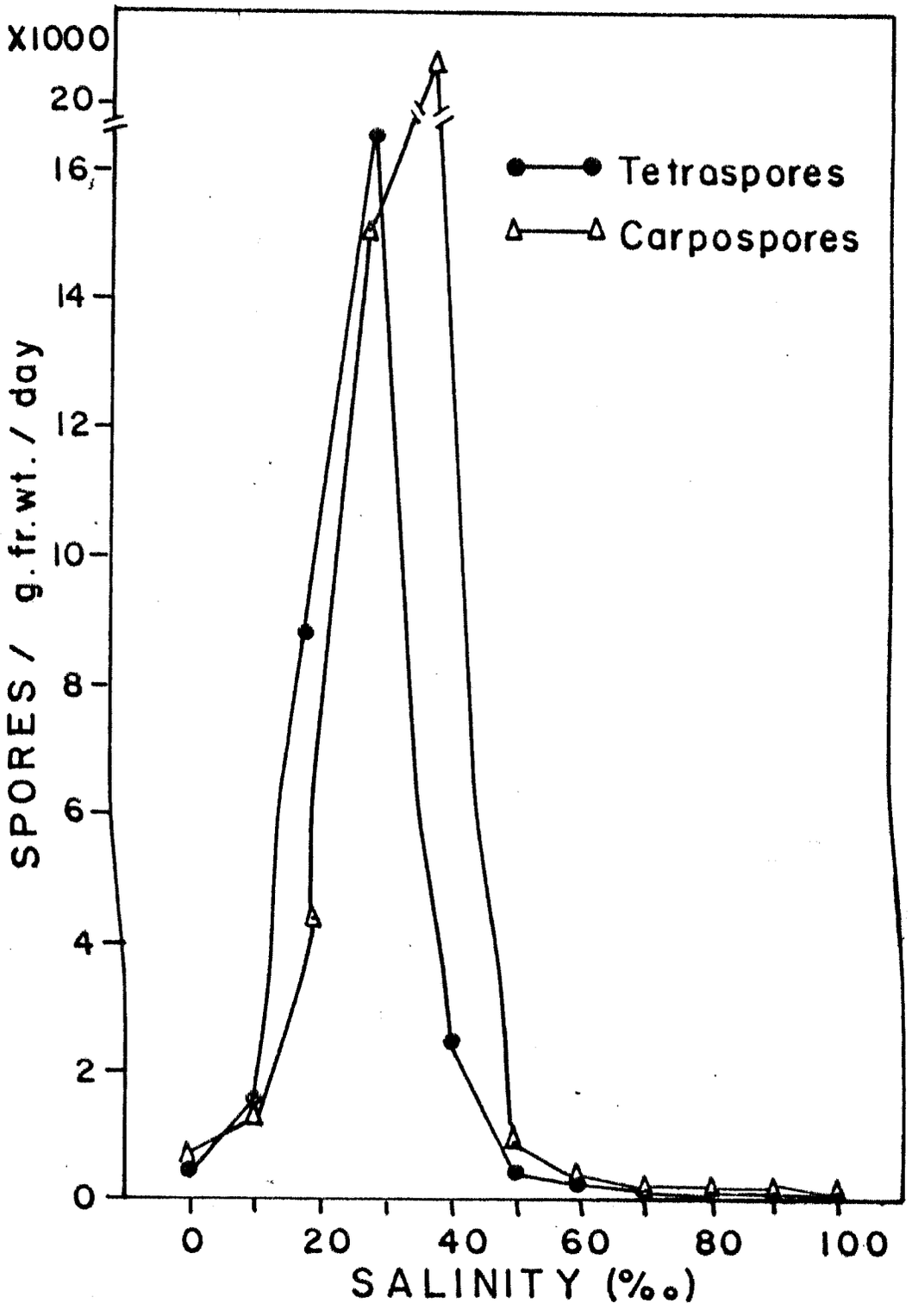


Figure No.24 Effect of salinity on tetraspore carpospore shedding in Gracilari edulis.

FIGURE 24

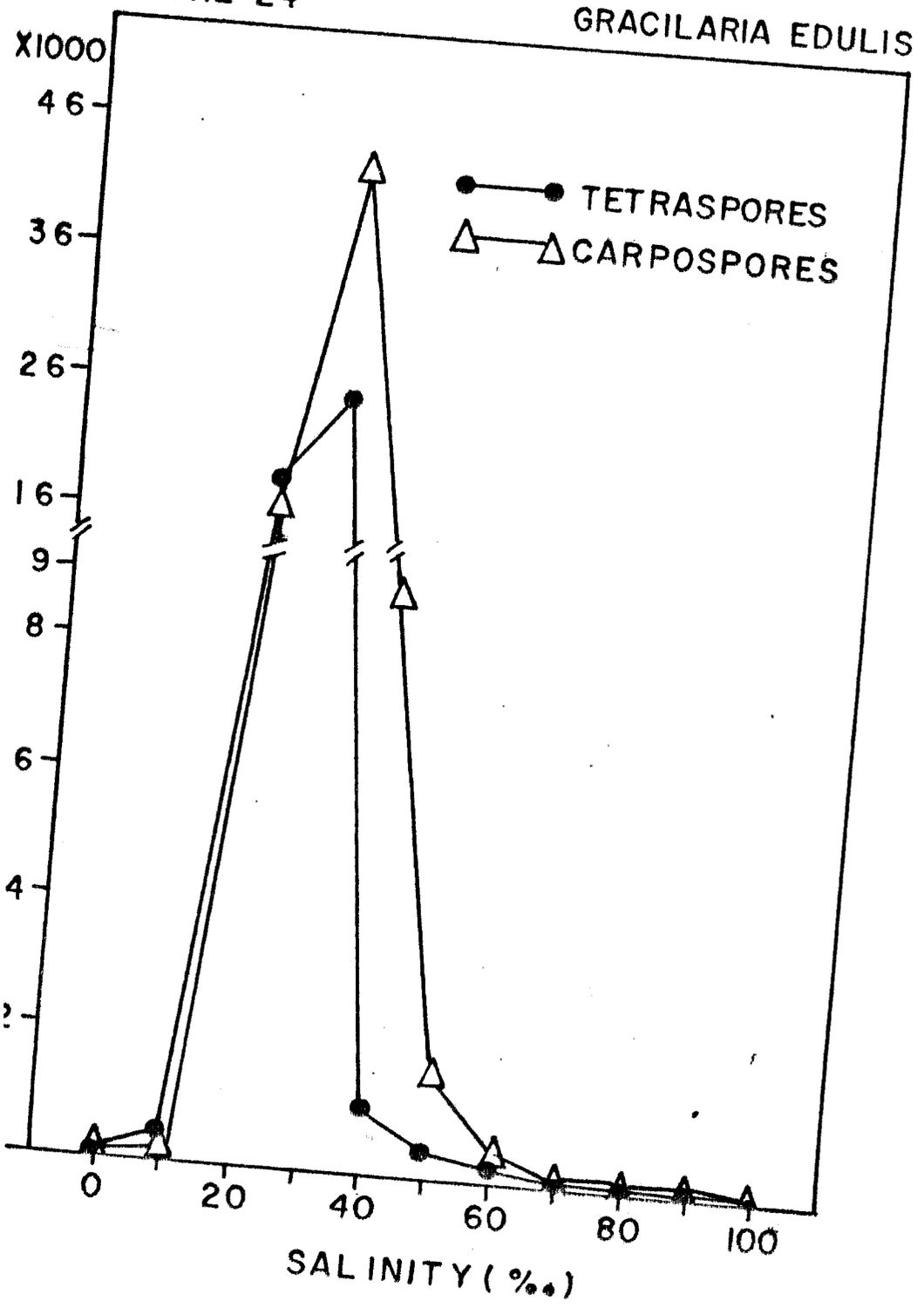
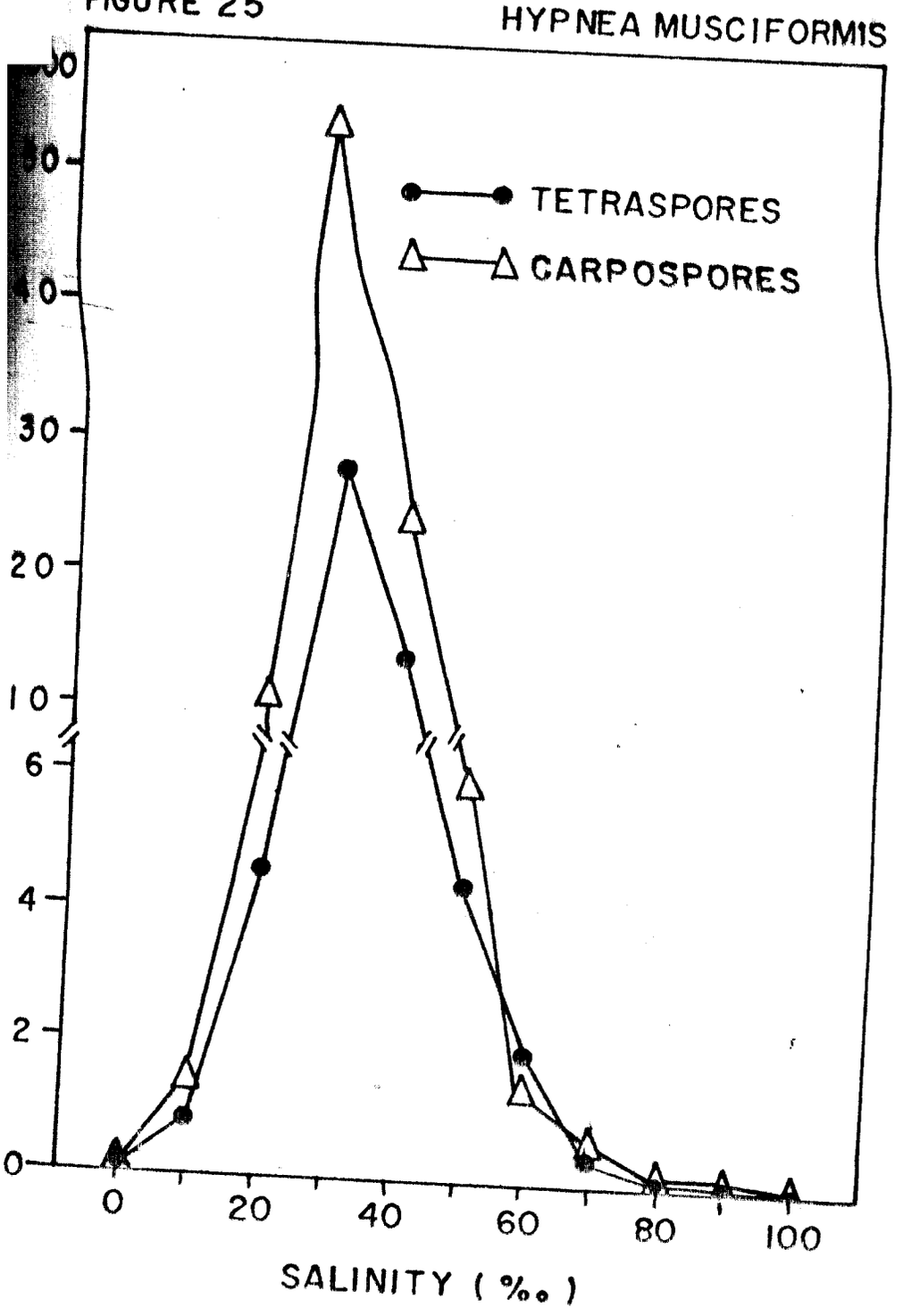

GRACILARIA EDULIS
X1000
46
36
26
16
9
8
6
4
2
TETRASPORES
CARPOSPORES
0
20
40
60
80
100
SALINITY (‰)

Figure No.25 Effect of salinity on the discharge of tetraspore and carpospore in Hypnea musciformis.

FIGURE 25


HYPNEA MUSCIFORMIS
TETRASPORES
CARPOSPORES
50
40
30
20
10
6
4
2
0
0
20
40
60
80
100
SALINITY (‰)

4.5.3 LIGHT INTENSITY

Figs. 26 to 29 show the quantity of spores liberated from Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis in dark (0 light intensity) and at 5 different light intensities ranging from 500 to 4000 lux (500, 1000, 2000, 3000 and 4000 lux). Spore output varied in different light intensities ranging from 0 to 4000 lux and spore shedding occurred in all 6 light intensities. The spore output in the four red algae was less in dark (0 light intensity), 2000, 3000 and 4000 lux light intensities. Peak discharge of tetraspores in Gelidiella acerosa, and tetraspores and carpospores of Gracilaria corticata and G. edulis was found at 500 lux. The quantity of spores liberated at 1000 lux was also high in these three species. In Hypnea musciformis maximum liberation of tetraspores as well as carpospores was observed at 1000 lux light intensity. More number of spores were released also at 500 lux light intensity.

4.5.4 TEMPERATURE

Changes observed in the spore output of Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis at 10 different temperatures (-15 °, 0 °, 5 °, 20 °, 25 °, 30 °, 35 °, 40 °, 45 ° and 50 °C) are given in Figs. 30 to 33.

In Gelidiella acerosa tetraspore liberation was not found at -15°, 45° and 50°C. Minimum quantity of spores was released at 0° and 40°C and the spore output values obtained at 5° and 35°C were also low. Maximum quantity of spores was liberated in the gelidiaceous alga between 20° and 35°C with peak at 25°C (Fig. 30).

In Gracilaria corticata there was no spore release at -15°, 0° and 50°C and spore output was minimum at 5° and 45°C. Peak discharge of tetraspores was observed at 30°C and carpospores at 25°C. The quantity of tetraspores and carpospores liberated in other temperatures was low (Fig.31).

Shedding of spores in Gracilaria edulis was minimum at 0°, 5°, 40° and 45°C and low spore output was found at 35°C. There was no spore output at -15° and 50°C. Though peak output of tetraspore was found at 30°C and carpospore liberation at 25°C, the spore output values obtained for tetraspores at 20° and 25°C and for carpospores at 20° and 30°C was also equally high in Gracilaria edulis(Fig.32).

In Hypnea musciformis discharge of tetraspores was not found at -15°, 0° and 50°C and carpospores at -15°, 0°, 40° and 45°C. More number of tetraspores and carpospore

liberation was observed between 20 °C and 35 °C with peak spore output at 30 °C for both tetraspores and carpospores. The spore output in other temperatures were comparatively low (Fig. 33).

4.5.5 PHOTOPERIOD

Figs. 34 to 40 gives the quantity of spores discharged from Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis with the effect of different light and dark cycles on spore shedding at three different light intensities. Data were obtained at a low light intensity of 500 lux, at a medium light intensity of 2000 lux and at a high light intensity of 4000 lux for all the four red algae. These light intensities were selected depending upon the daily spore output observed in these algae (Figs. 26 - 29). In these experiments, planned to study the combining effects of day length and light energy, peak spore output varied with the duration of light intensity in different light and dark regimes.

In Gelidiella acerosa at a low light intensity of 500 lux, tetraspore output increased from 0 + $\overline{24}$ LD cycle and maximum sporulation was observed at 12 : $\overline{12}$ hrs LD cycle. With further increase in light period, though the spore output decreased (Fig. 34) the values obtained were higher than that at 0 + $\overline{24}$ LD cycle. At 2000 lux light intensity

Figure No.26 Effect of light intensity on the shedding of tetraspores in *Gelidiella acerosa*.

FIGURE 26 GELIDIELLA ACEROSA

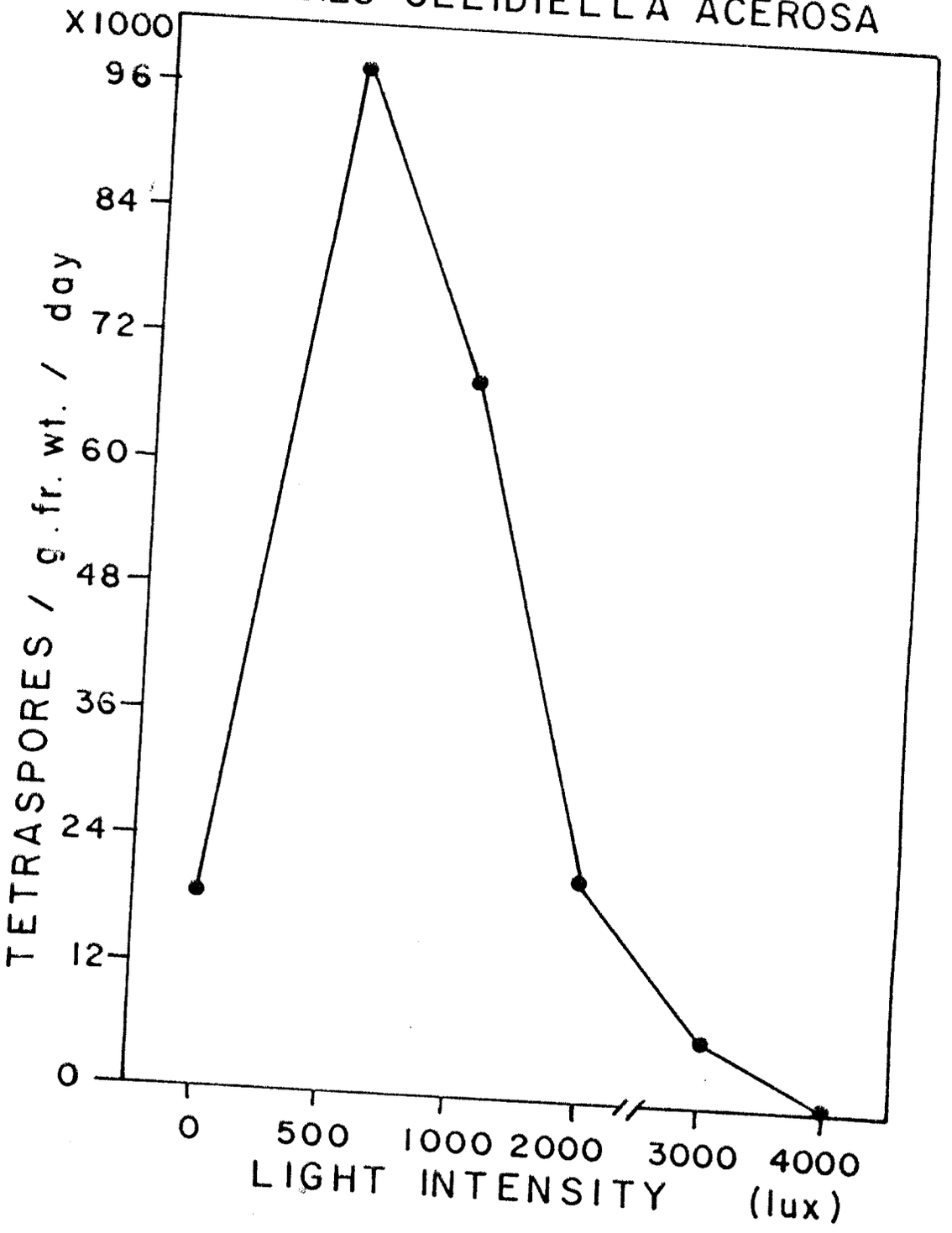


Figure No.27 Effect of light intensity on the tetraspore and carpospore output of Gracilaria corticata.

FIGURE 27. GRACILARIA CORTICATA

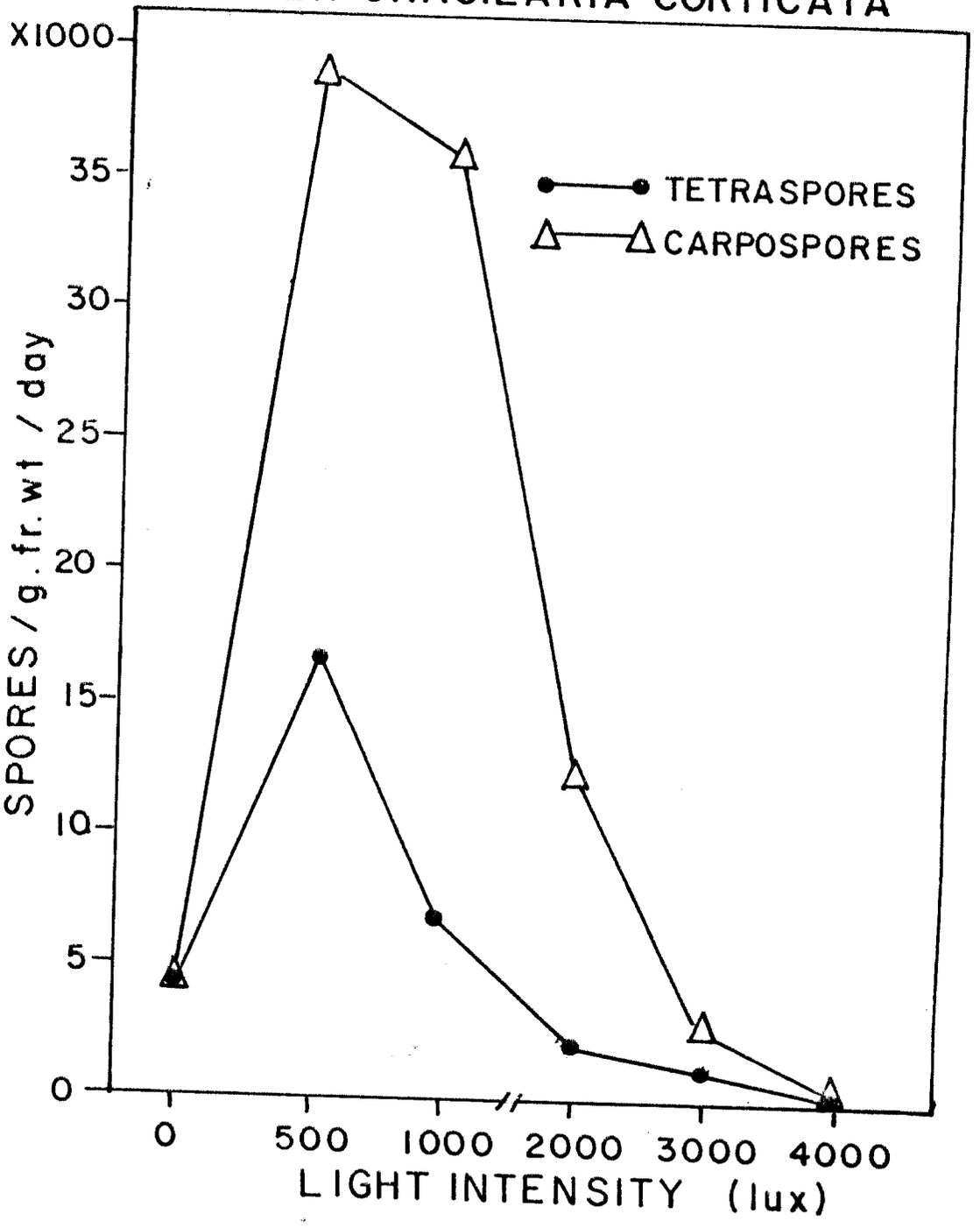


Figure No.28 Effect of light intensity on the liberation of tetraspores and carpospores in *Gracilaria edulis*.

FIGURE.28. GRACILARIA EDULIS

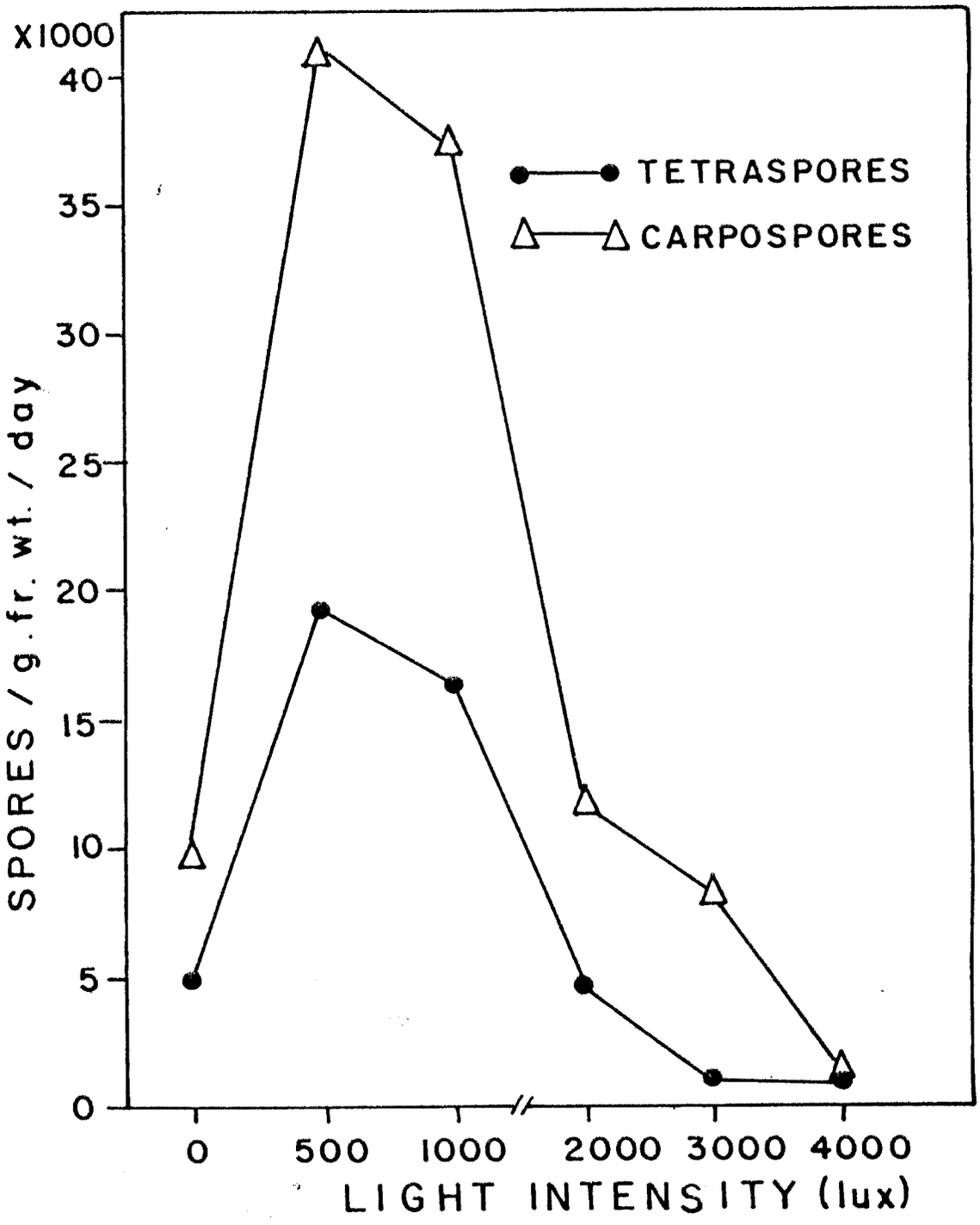


Figure No.29 Effect of light intensity on the tetraspore and carpospore output of *Hypnea musciformis*.

FIGURE.29. HYPNEA MUSCIFORMIS

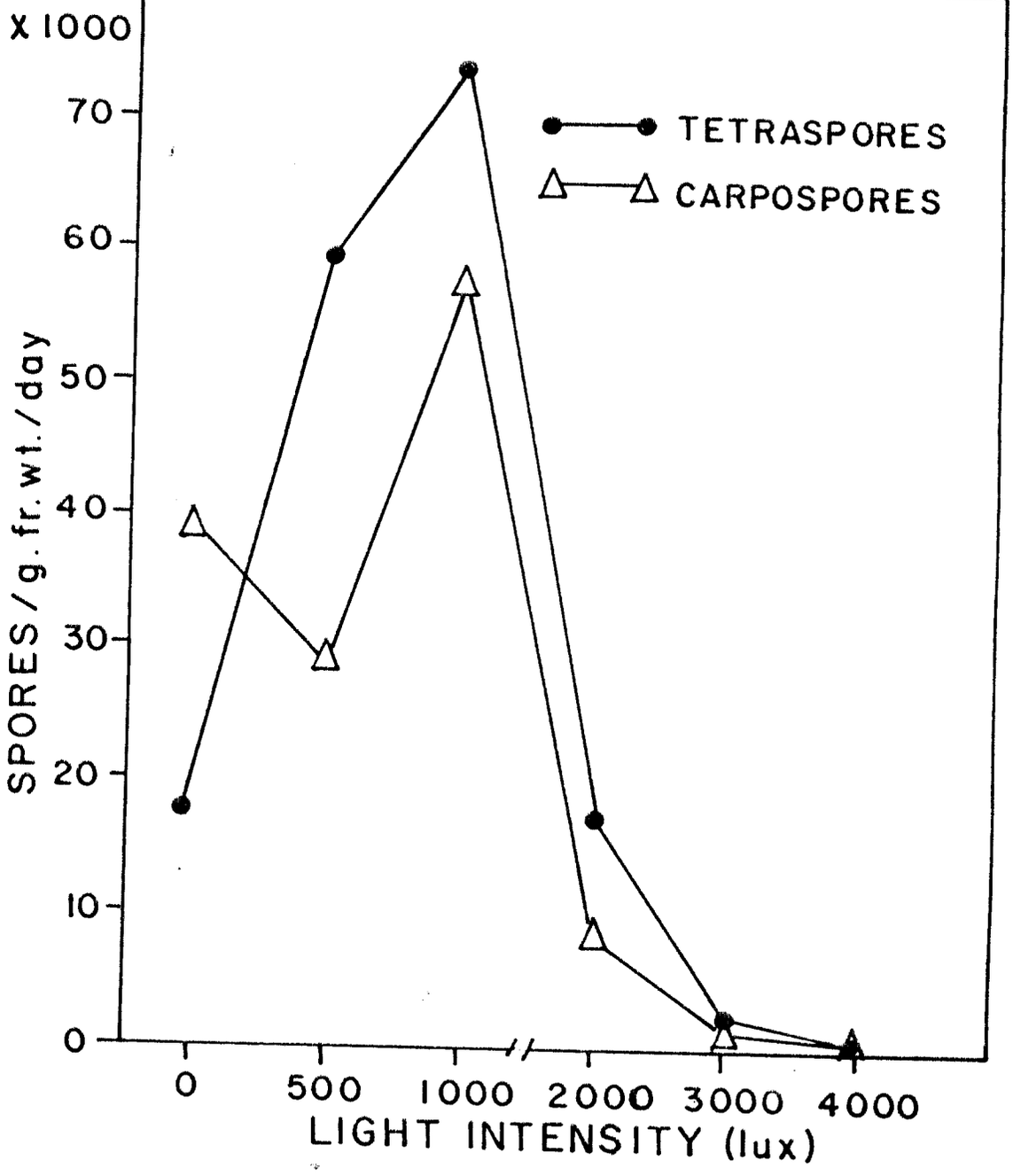


Figure No.30 Effect of temperature on the release of tetraspores in *Gelidiella acerosa*.

FIGURE.30. GELIDIELLA ACEROSA

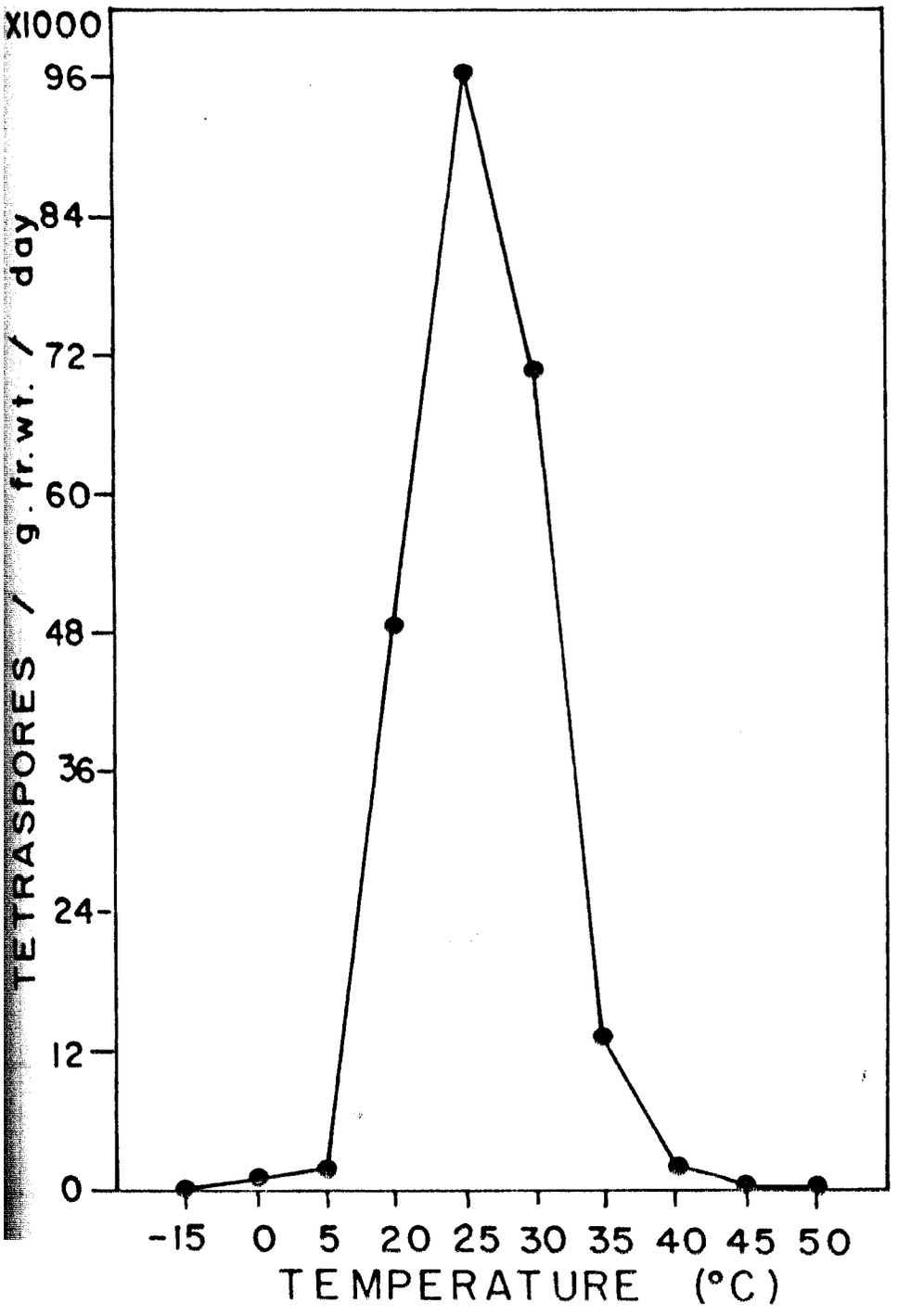


Figure No.31 Effect of temperature on tetraspore and carpospore shedding in Gracilaria corticata.

FIGURE.31. GRACILARIA CORTICATA

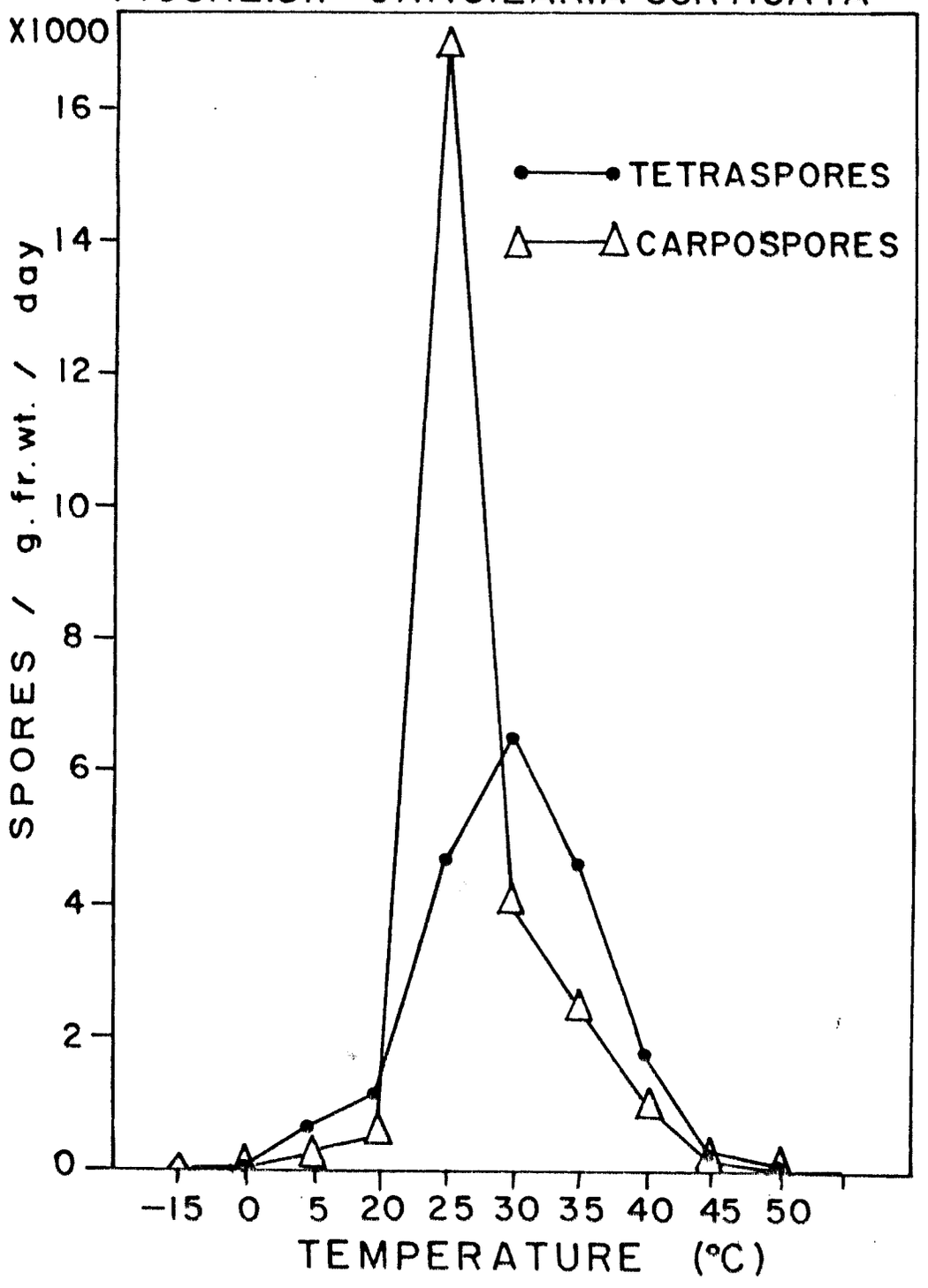


Figure No.32 Effect of temperature on liberation of tetraspores and carpospores in *Gracilaria edulis*.

FIGURE .32. GRACILARIA EDULIS

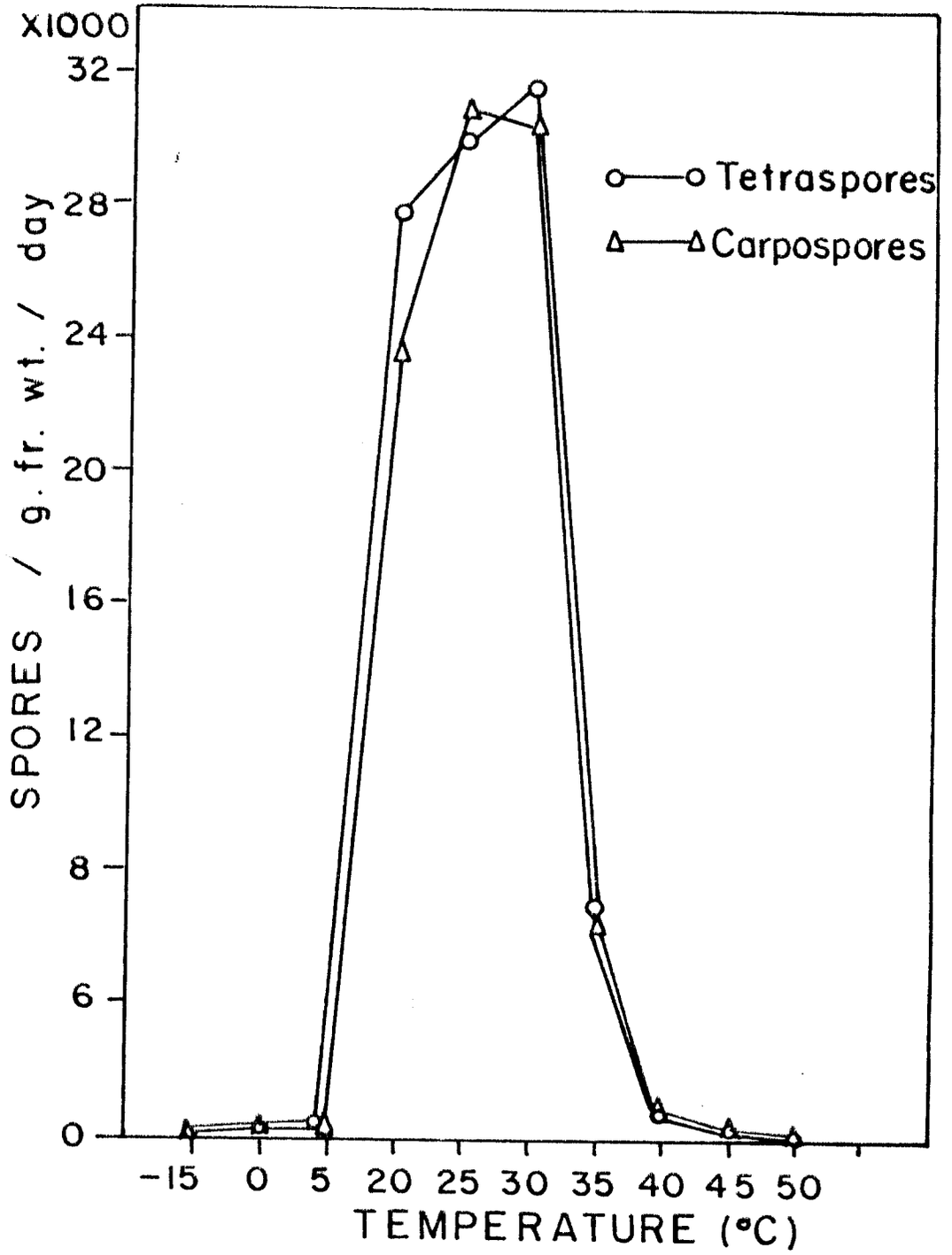


Figure No.33 Effect of temperature on tetraspore and carpospore output in Hypnea musciformis.

FIGURE.33. HYPNEA MUSCIFORMIS

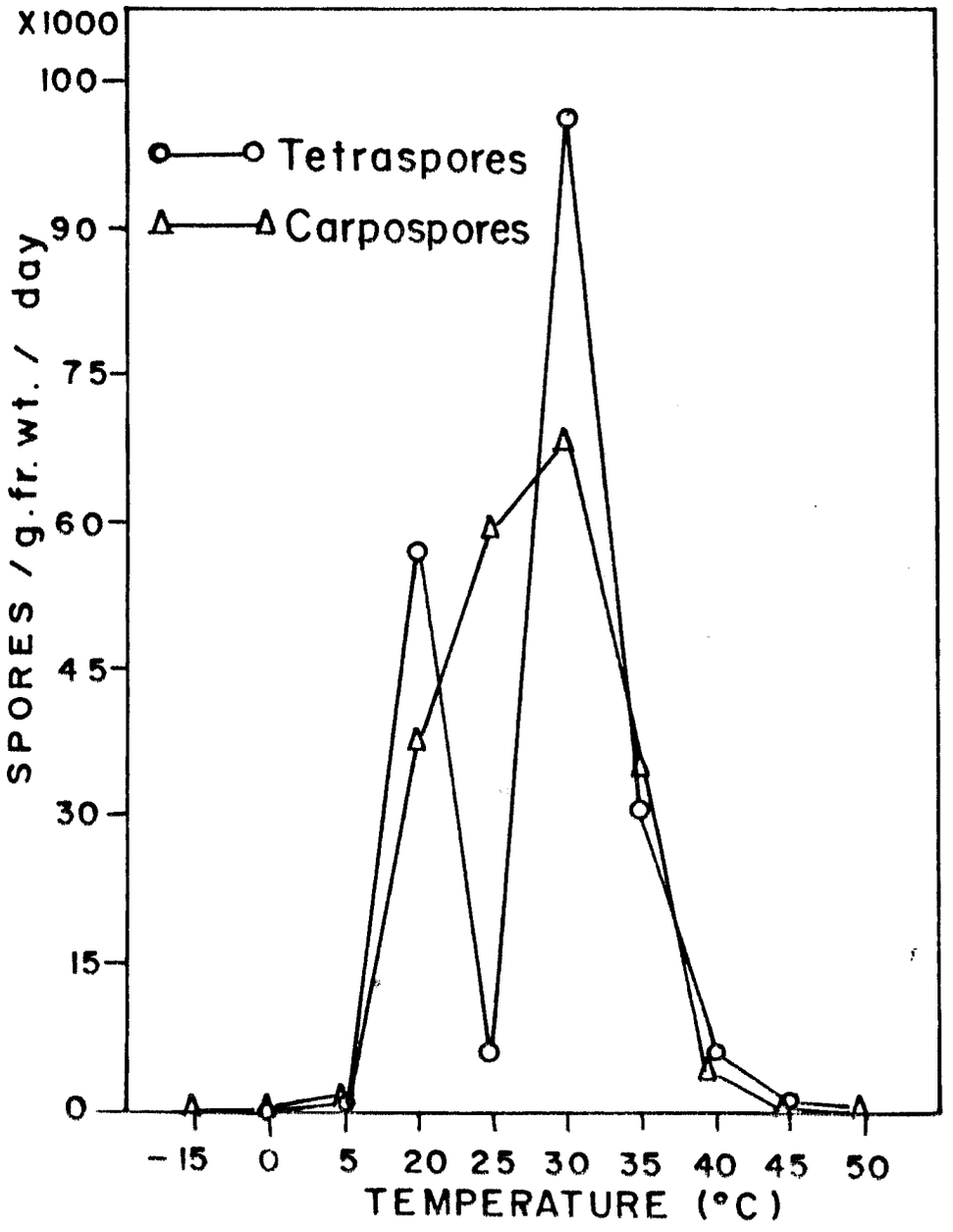
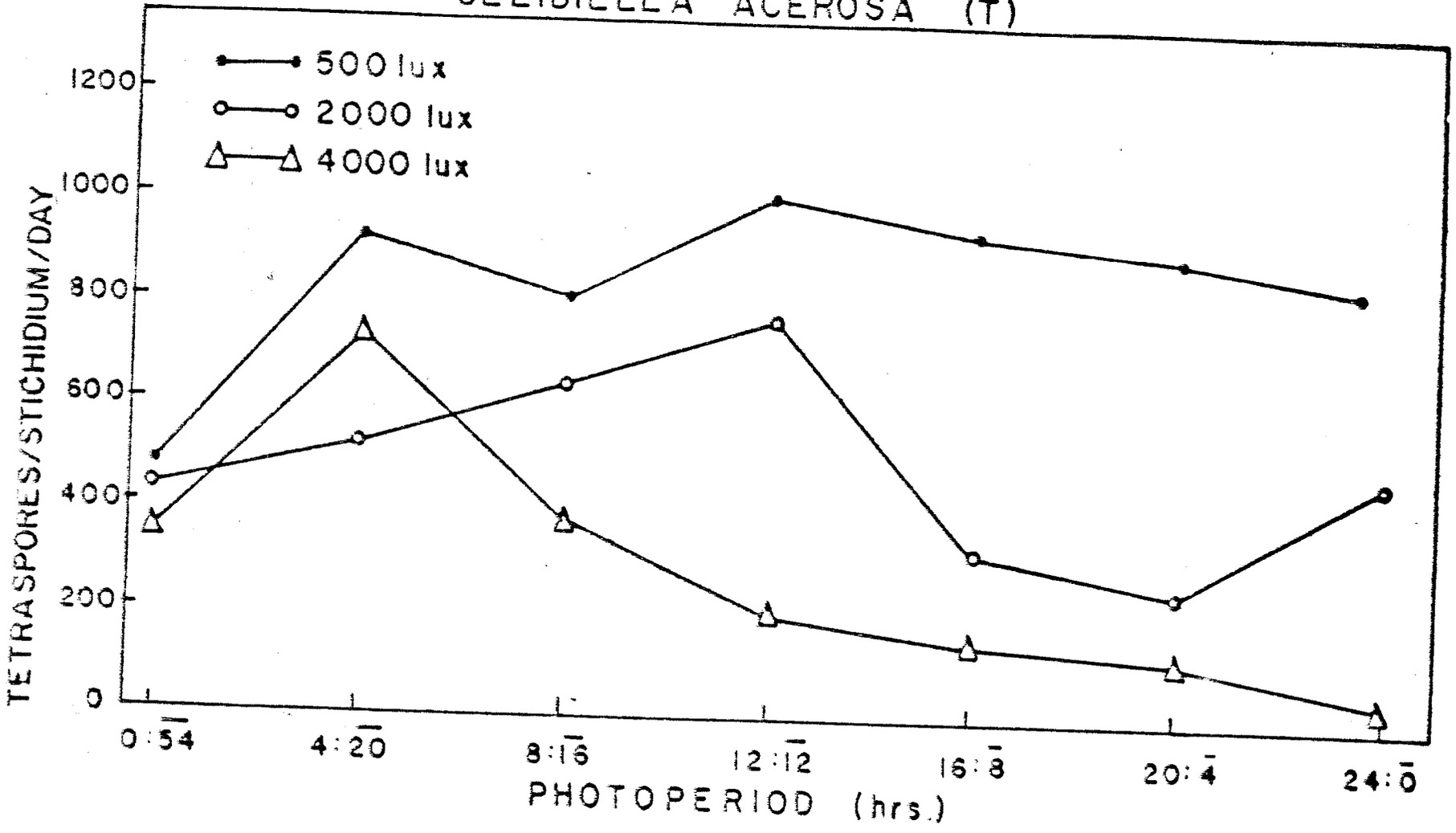


Figure No.34 Combined effects of photoperiod and light intensity on the tetraspore discharge in Gelidiella acerosa.

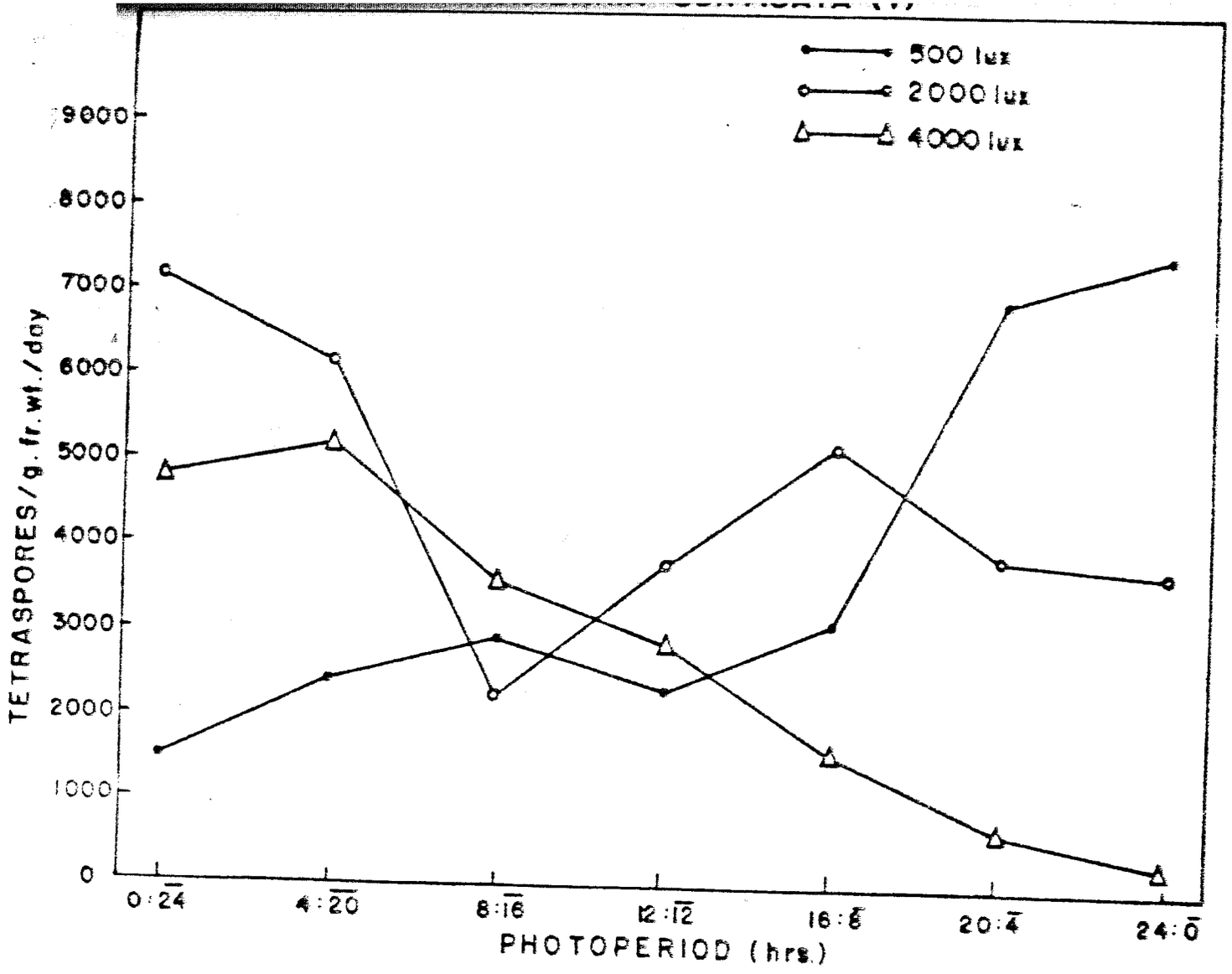
FIGURE 34. GELIDIELLA ACEROSA (T)



the values obtained at 4 : $\overline{20}$ LD cycle were higher than in complete darkness (0 + $\overline{24}$ LD cycle) and peak liberation of spores was higher observed in 12 : $\overline{12}$ LD cycle. Spore output decreased with further increase in the photoperiod at the intensity after 12 : $\overline{12}$ LD cycle. At 4000 lux light intensity, spore output was high at 4 : $\overline{20}$ LD cycle than at complete darkness (0 lux) but spore number was comparatively higher than that obtained at 8 : $\overline{16}$ LD, 12 L : $\overline{12}$ D, 16 L : $\overline{8}$ D to 24 L : $\overline{0}$ D photoregime (Fig. 34).

In Gracilaria corticata (Fig. 35) at 500 lux light intensity, slight increase in tetraspore release was seen from 0 + $\overline{24}$ to 12 : $\overline{12}$ hrs LD cycle, after which spore output increased greatly and highest number of spores was observed at 24 : $\overline{0}$ LD photo regime. At 2000 lux, peak liberation of tetraspore was seen at 0 : $\overline{24}$ (complete darkness), whereas in 4 L : $\overline{20}$ D photo regime spore liberation was higher than that observed for other photo regimes (i.e., 8 : $\overline{16}$ LD cycle onwards) shown in (Fig. 35). At 4000 lux light intensity, maximum spore liberation was observed at 4 : $\overline{20}$ LD cycle and at other light and dark period spore output decreased (Fig. 35). In the carpospore output of the same species (Fig. 36) at 500 lux, maximum spore liberation was seen at 24 : $\overline{0}$ LD cycle. Spore output increased with the increase in the duration of light intensity. Spore output at 0 light intensity (complete darkness) was also higher than that

Figure No.35 Combined effects of photoperiod and light intensity on the tetraspor discharge in Gracilaria corticata.


500 lux
2000 lux
4000 lux
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
TETRASPORES / g. fr. wt. / day
0:24
4:20
8:16
12:12
16:8
20:4
24:0
PHOTOPERIOD (hrs.)

observed at 4 : $\overline{20}$ LD cycle (Fig.36). At 2000 lux light intensity, spore output increased with the increase in the duration of light intensity and peak liberation was observed at complete illumination (24 + $\overline{0}$ LD cycle). In 4000 lux, maximum spore shedding was observed at 4 : $\overline{20}$ LD cycle. At 8 : $\overline{16}$ LD cycle spore output decreased (Fig. 36).

Fig. 37 shows the carpospore output of Gracilaria edulis. At 500 lux, spore output increased with duration of light and maximum carpospore release was observed at 20 : $\overline{4}$ and 24 : $\overline{0}$ LD cycle. At 2000 lux, maximum spore release was seen at 16 : $\overline{8}$ LD cycle. Spore output in complete darkness was higher than that at 4 : $\overline{20}$ and 8 : $\overline{16}$ LD cycle (Fig.37). At 4000 lux, light intensity, high spore output was observed at 4 : $\overline{20}$ LD cycle. After 8 : $\overline{16}$ LD cycle. Spore liberation decreased greatly.

The tetraspore output of Gracilaria edulis is given in Fig. 38. At 500 lux light intensity, maximum spore discharge was found at 20 : $\overline{4}$ LD cycle. At photo regimes of 16 : $\overline{8}$ and 24 : $\overline{0}$ spore output was more or less of equal nature (Fig. 38). At 2000 lux light intensity, spore output was very high at 8 : $\overline{16}$ and 12 : $\overline{12}$ LD cycle. Spore output at 0 light intensity was higher than that at 4 : $\overline{20}$ and 16 : $\overline{8}$ LD cycle. At 20 : $\overline{4}$ and 24 : $\overline{0}$ LD cycle, spore

liberation was higher than that in complete darkness, 4 : $\overline{20}$ and 16 : $\overline{8}$ LD cycle. At 4000 lux light intensity, spore shedding was high in complete darkness and maximum spores were observed at 4 : $\overline{20}$ LD cycle, which decreased with increase in photoperiods. (Fig. 38)

Carpospore liberation of Hypnea musciformis is given in Fig. 39. At 500 lux light intensity, spore output increased with increase in the duration of light energy. Maximum spore shedding was seen at 16 : $\overline{8}$ LD cycle. Spore output was also high at 20 : $\overline{4}$ and at complete illumination (24 : $\overline{0}$). At 2000 lux light energy, spore output was maximum in dark (0 light energy) and decreased successively at 4 : $\overline{20}$, 8 : $\overline{16}$, 12 : $\overline{12}$, 20 : $\overline{4}$ and 24 : $\overline{0}$ LD cycles. At 16 : $\overline{8}$ LD cycles carpospore output was as high as observed in 0 light energy. At 4000 lux light intensity, maximum spore liberation was observed in 0 : $\overline{24}$ LD cycle (0 light intensity). The value obtained at 4 : $\overline{20}$ LD cycle was less than that obtained at 0 : $\overline{24}$ LD cycle. But higher than 8 : 16 LD cycle. The spore output then decreased successively in the other LD cycles (Fig. 39).

Figure No.36 Combined effects of photoperiod and light intensity on carpospore output in Gracilaria corticata.

FIGURE - 36.

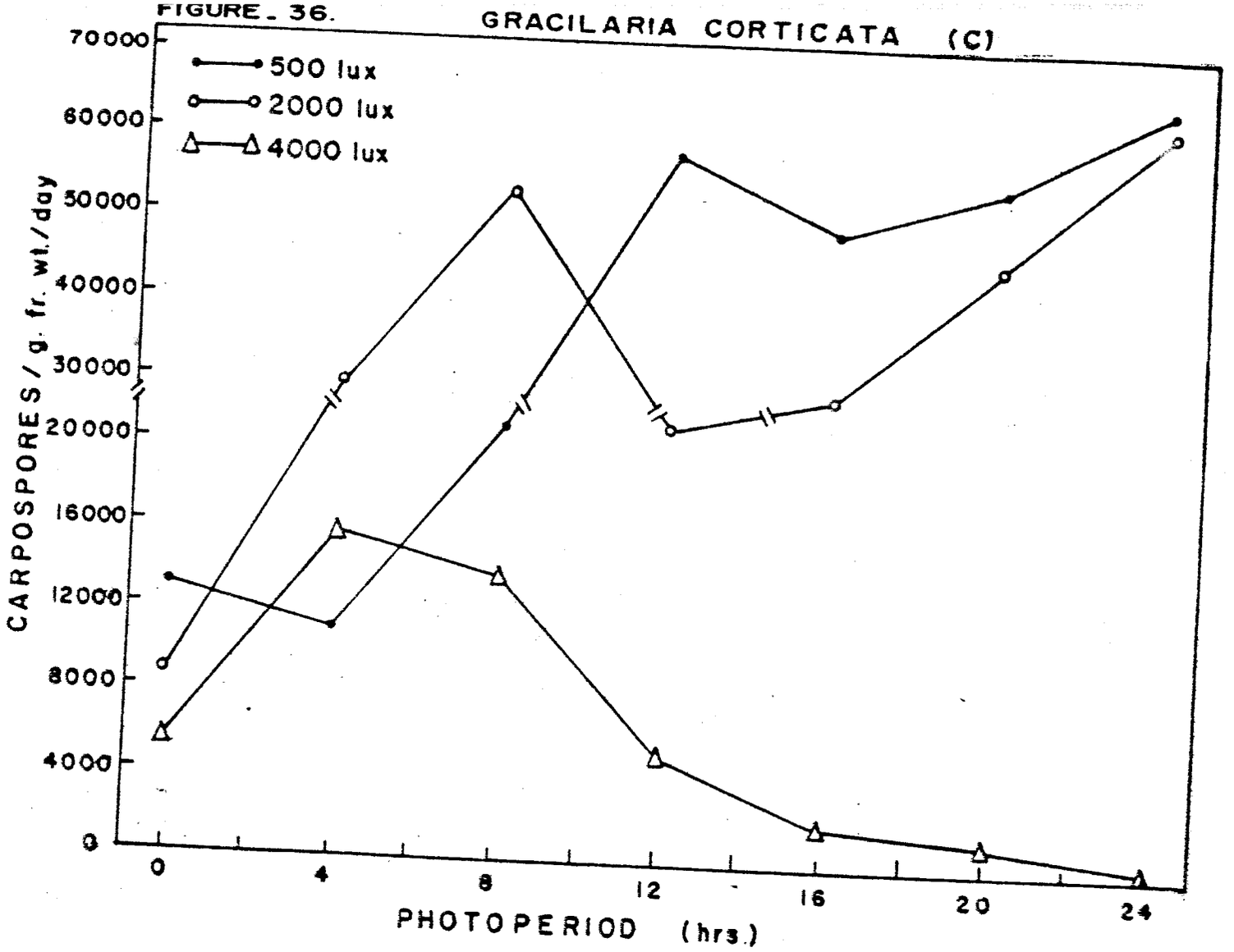

GRACILARIA CORTICATA (C)
500 lux
2000 lux
4000 lux
CARPOSPORES / g. fr. wt. / day
70000
60000
50000
40000
30000
20000
16000
12000
8000
4000
0
0
4
8
12
16
20
24
PHOTOPERIOD (hrs.)

Figure No.37 Combined effects of photoperiod and light intensity on the carpospore output in *Gracilaria edulis*.

FIGURE_37. GRACILARIA EDULIS (C)

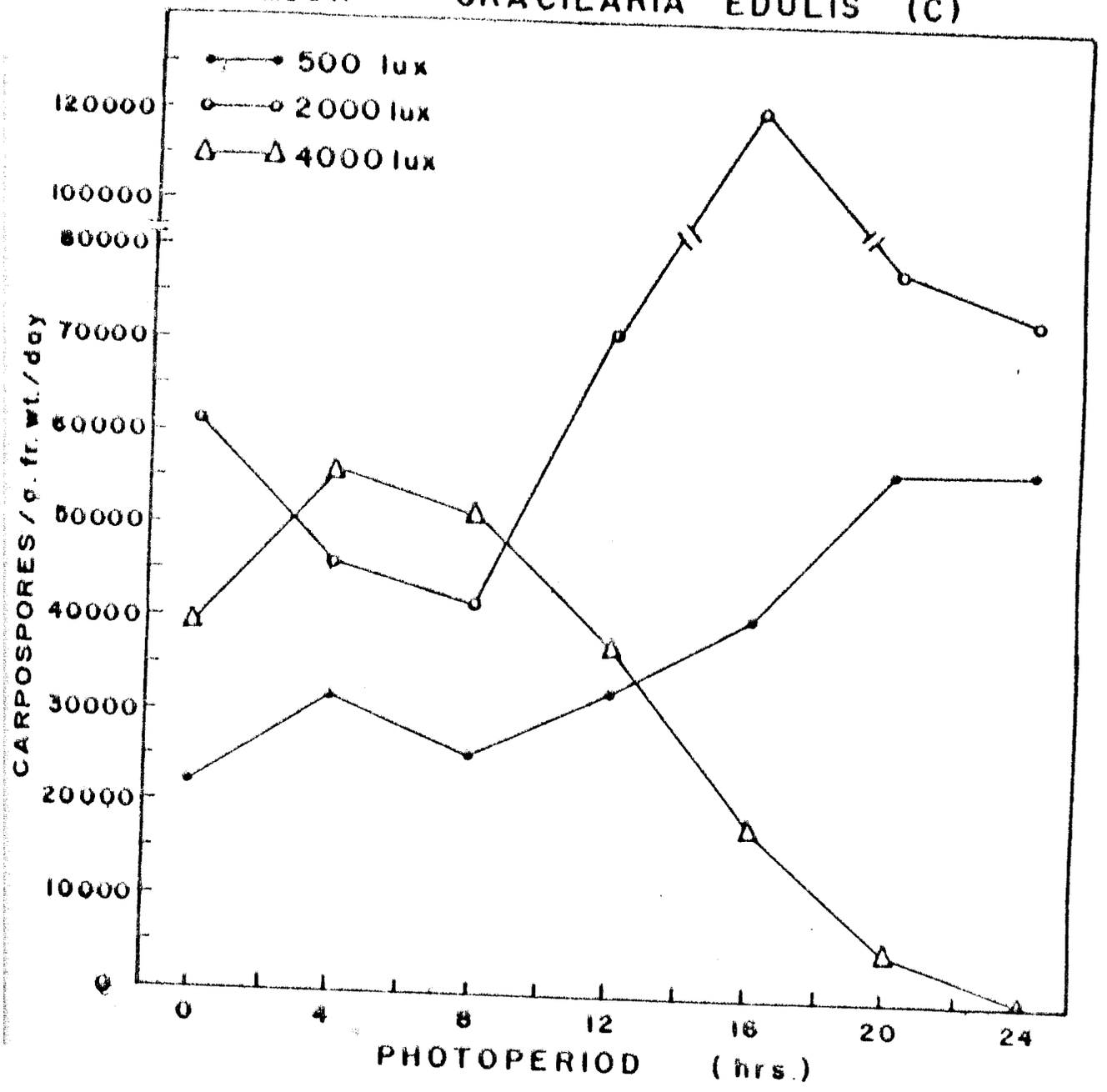


Figure No.38 Combined effects of photoperiod and light intensity on the tetraspore output in Gracilaria edulis.

FIGURE _ 38. GRACILARIA EDULIS (T)

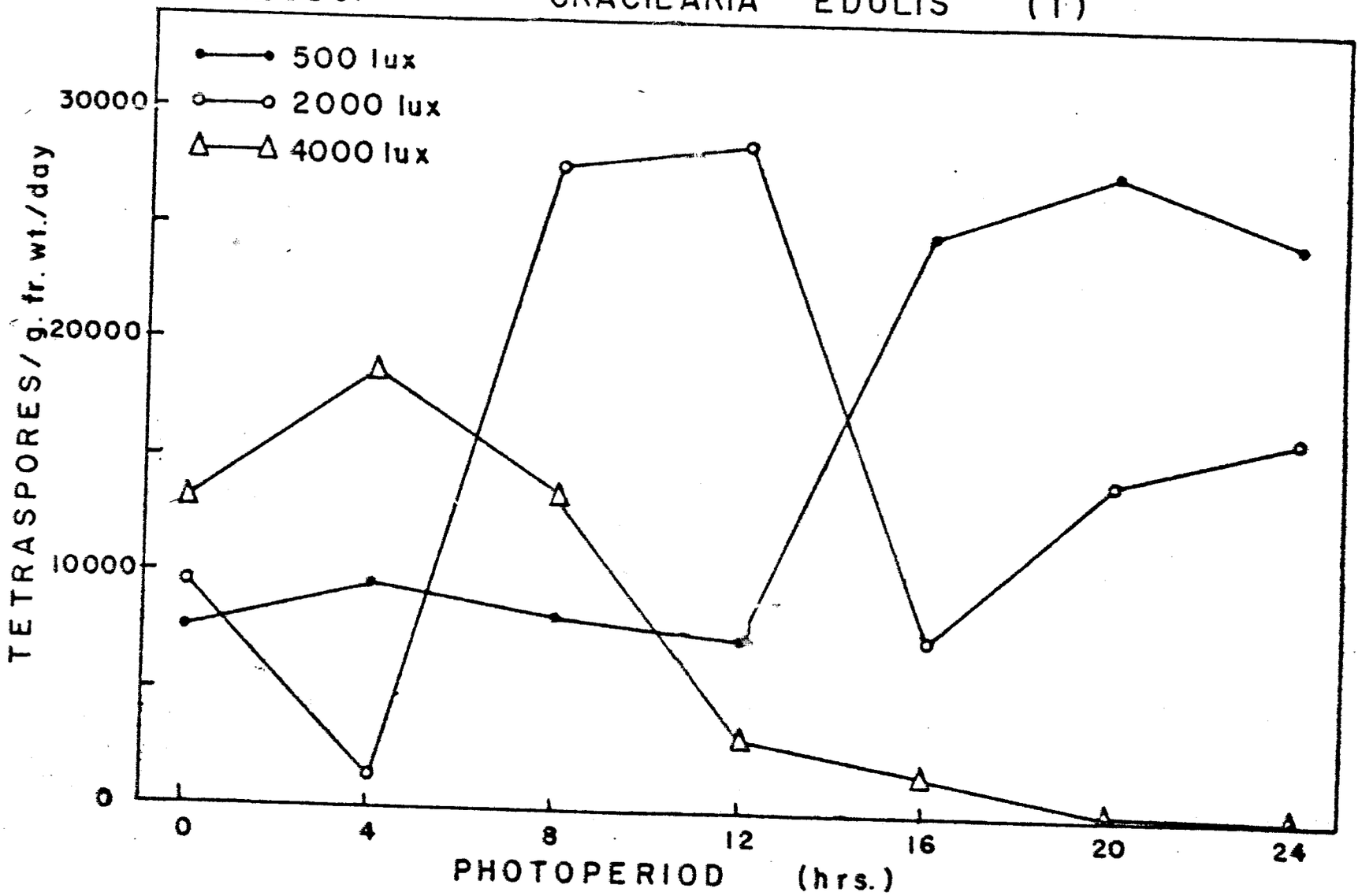


Figure No.39 Combined effects of photoperiod and light intensity on the carpospore output in Hypnea musciformis.

FIGURE-39 HYPNEA MUSCIFORMIS (C)

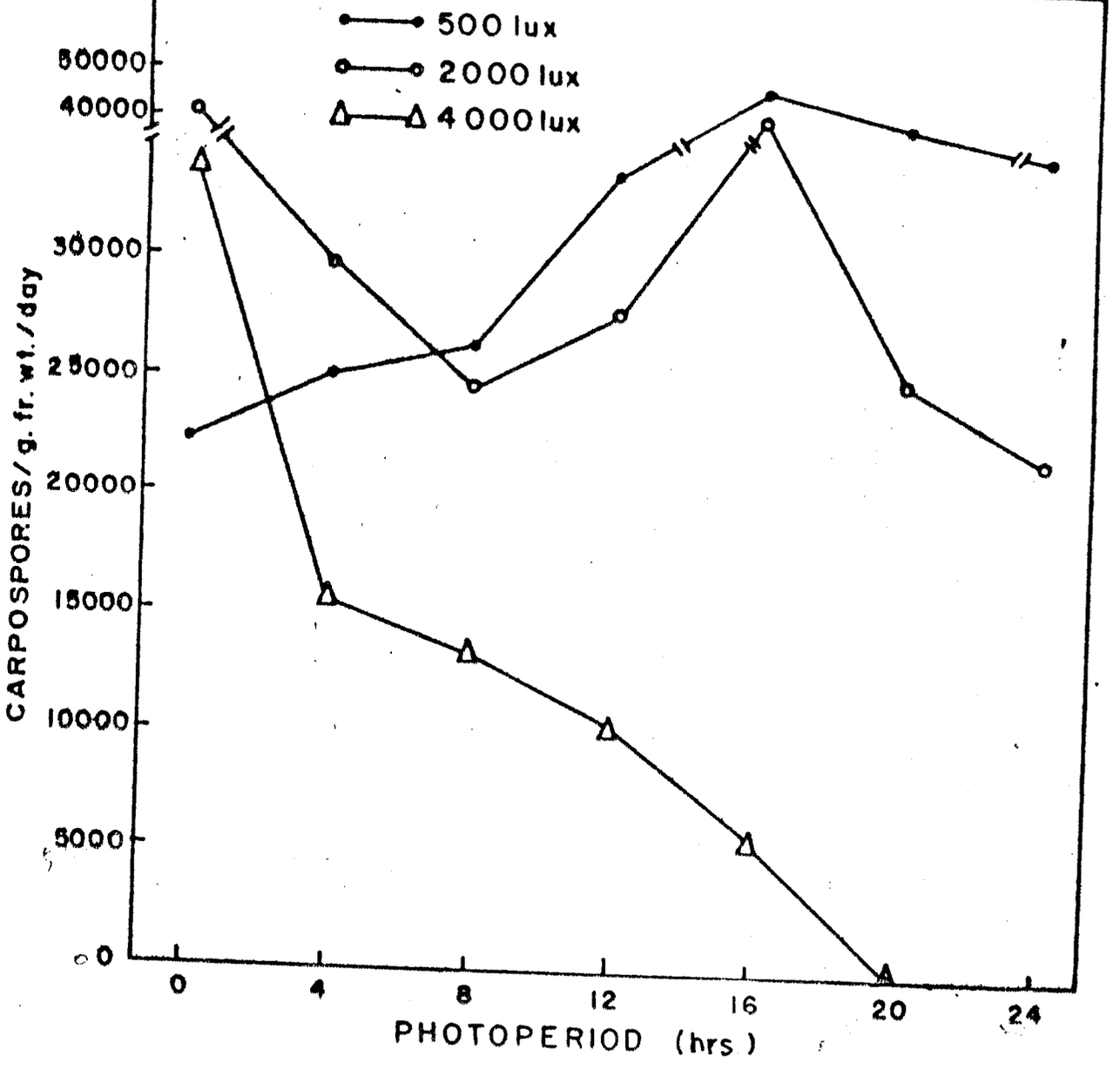


Fig. 40 shows the tetraspore output of Hypnea musciformis at three different light intensities (500, 2000 and 4000 lux). At 500 lux, spore output increased with increase in the duration of light energy from 0 : $\overline{24}$ LD cycle and maximum spore output was seen at continuous illumination (24+0 LD cycle). At 2000 lux light intensity, the value obtained at 12 : $\overline{12}$ and 24 : $\overline{0}$ LD cycle showed maximum spore output than at 0 : $\overline{24}$, 4 : $\overline{20}$, 8 : $\overline{16}$, 16 : $\overline{8}$ and 20 : $\overline{4}$ LD cycles, but were slightly higher than at 0 : $\overline{24}$ LD cycle. At 4000 lux, spore output was high in 0 + $\overline{24}$ LD cycle and maximum spore discharge was seen at 8 : $\overline{16}$ LD cycle. In the other LD cycles (12 : $\overline{12}$, 16 : $\overline{8}$, 20 : $\overline{4}$ and 24 : $\overline{0}$) spore output decreased greatly(Fig.40).

4.6 GERMINATION OF SPORES

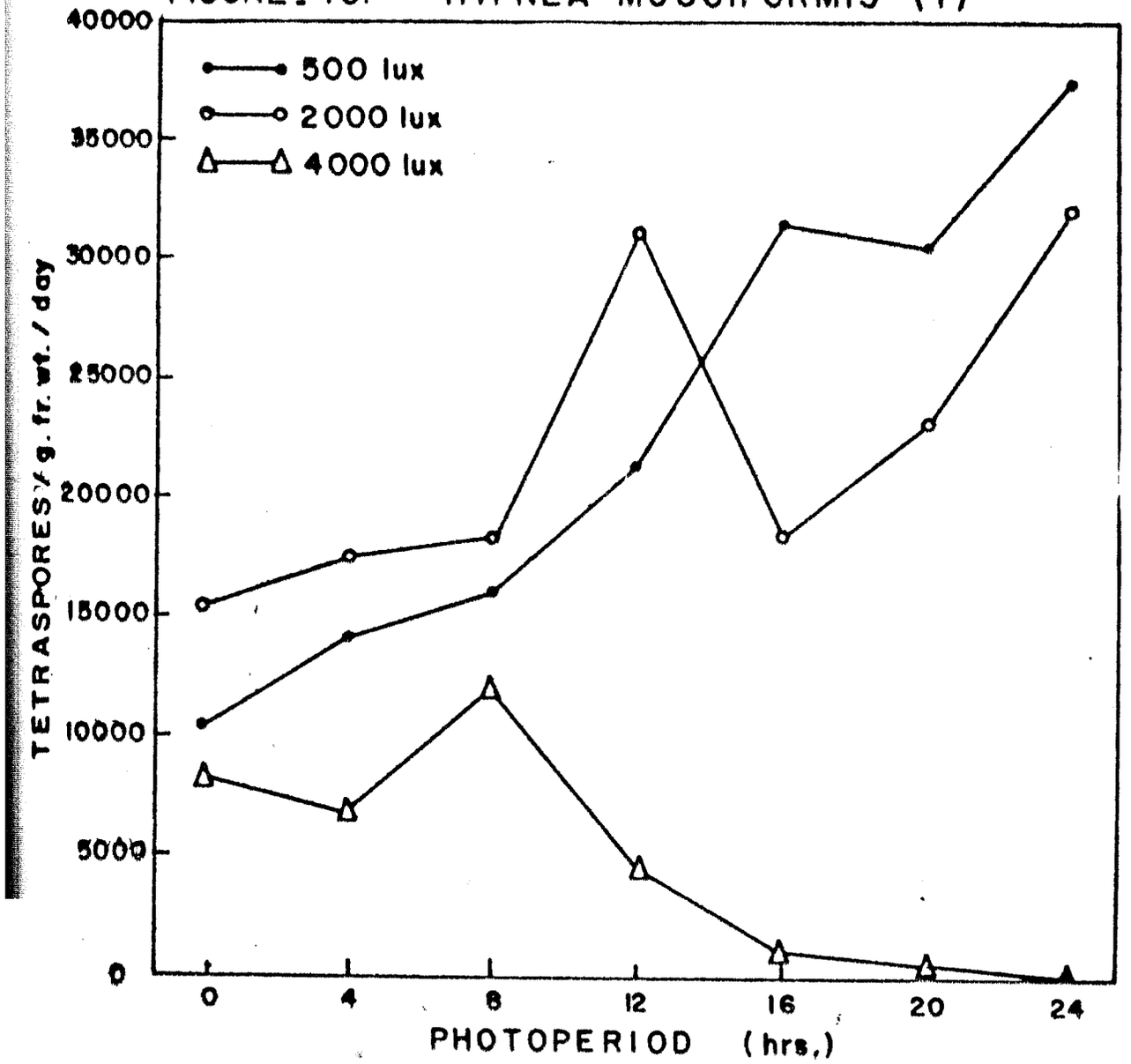
Data obtained on the percentage frequency of germinating tetraspores of Gelidiella acerosa and tetraspore and carpospores of Gracilaria corticata, G. edulis and Hypnea musciformis are given in Figures (41 - 44).

GERMINATION OF SPORES IN DIFFERENT MONTHS OF THE YEAR

Monthly means estimated for two years data are plotted to show the general trend in the germination of spores liberated in different months of the year. In Gelidiella acerosa the germination rate of tetraspores varied seasonally from a

Figure No.40 Combined effects of photoperiod and light intensity on the tetraspore output in Hypnea musciformis.

FIGURE.40. HYPNEA MUSCIFORMIS (T)



minimum of 12 % to a maximum of 91 %. Highest rate of germination (within 24 hours period) was observed in January - February - March and also in July - August 83 (Fig. 41.1). In tetraspores and carpospores of Gracilaria corticata, G. edulis and Hypnea musciformis, (Fig.41.2-44) germination of spores was observed throughout the year and highest rate of germination was observed in the months of October, November, December '81, December - January '83 for Gracilaria corticata and Gracilaria edulis. In Hypnea musciformis highest rate of germination was observed in the months of August - September, 1982, February 1983, July 1983, for tetraspores and for carpospores from Pudumadam was observed in the months of August '82, December '82, January '83, February '83 and October '83. In the carposporic plants (Hypnea musciformis) collected from Kilakarai, germination of carpospores was observed highest in the months of July '82, November '82, and September '83, though germination of spores was observed in all the months of the year, which mostly depended upon the maturity of the spores during liberation and optimum conditions available during and after liberation. Dividing spores were observed within 24 hours of liberation in Gelidiella acerosa, Gracilaria corticata, G. edulis, and Hypnea musciformis during the two years of seasonal study on spore output.

EXPOSURE TO AIR

Data observed on the germination of tetraspore of Gelidiella acerosa and tetraspore and carpospore of Gracilaria corticata, G. edulis and Hypnea musciformis in different experiments conducted to study the effects of environmental factors are given in Figs. 45 - 54. In Gelidiella acerosa tetraspores showed maximum germination in control (0 minute exposure) (Fig.45A) than the fronds (with fertile stichidia) exposed to 15 minutes exposure and above showed decrease in germination of spores. Spores did not germinate in the fronds exposed to 90 minutes. In Gracilaria corticata, maximum germination within 24 hours was seen in control in tetraspore while tetrasporic frond exposed to air showed decrease in germination of tetraspores and there was no germination in the fronds exposed to 120 minutes (Fig.45B). The carposporic frond exposed to air for 15 minutes showed more germination than the control. Carpospores also germinated in the fronds exposed to 150 minutes. There was decrease in germination of carpospores with increase in exposure after 30 minutes. There was no germination in the fronds exposed to 2½ hours. In the experiments conducted at room temperature with Gracilaria edulis, maximum germination rate was seen in the controls and the germination rate decreased with increase in the duration of exposure

Figure No.41 Seasonal variations in the germinatio
of tetraspores of (1) Gelidiella acer
AND (2) Gracilaria corticata.

FIGURE-41. SEASONAL VARIATION IN SPORE GERMINATION

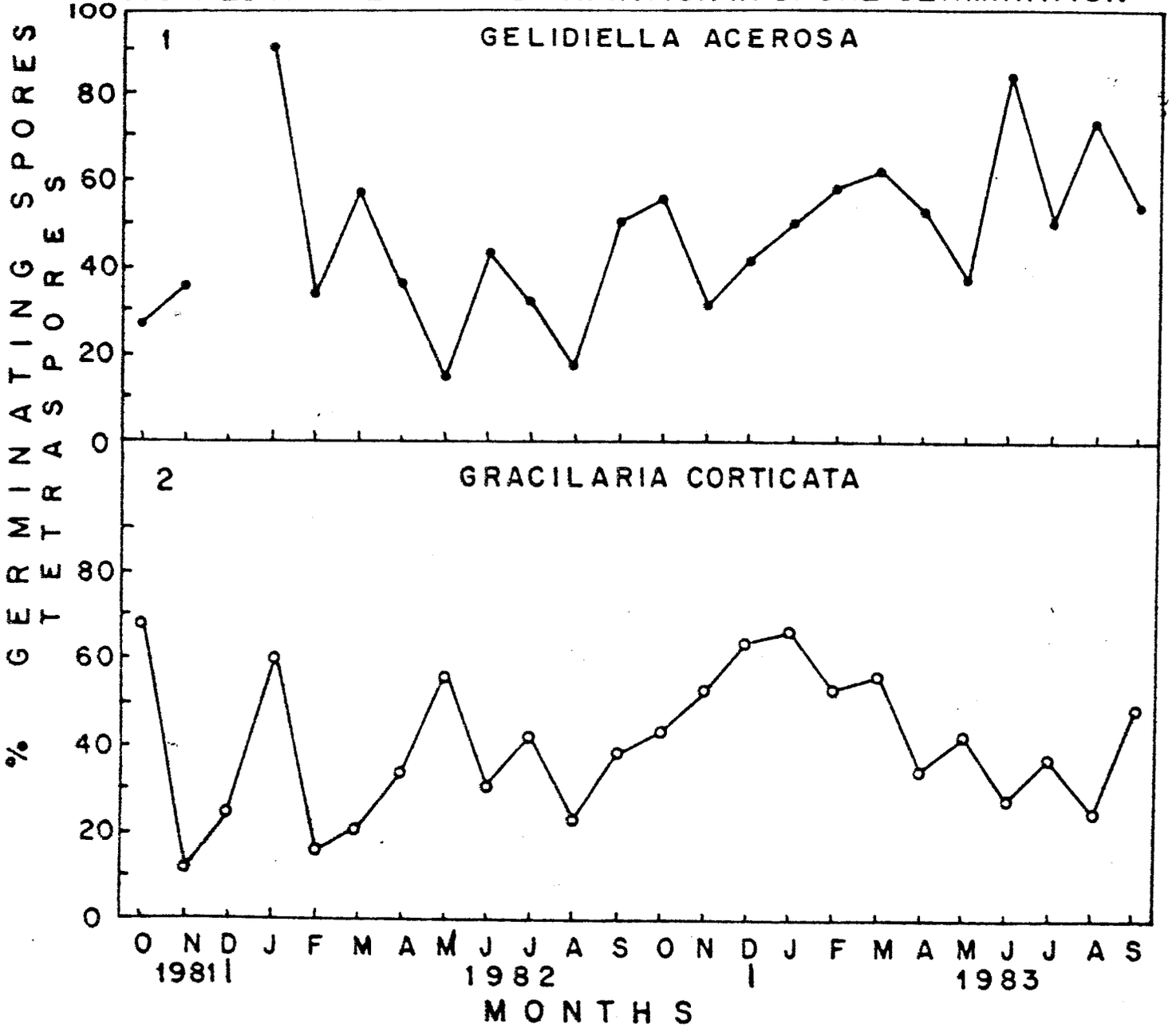


Figure No.42 Seasonal variations in the germination of (1) carpospores of Gracilaria corti (2) tetraspore of Gracilaria edulis.

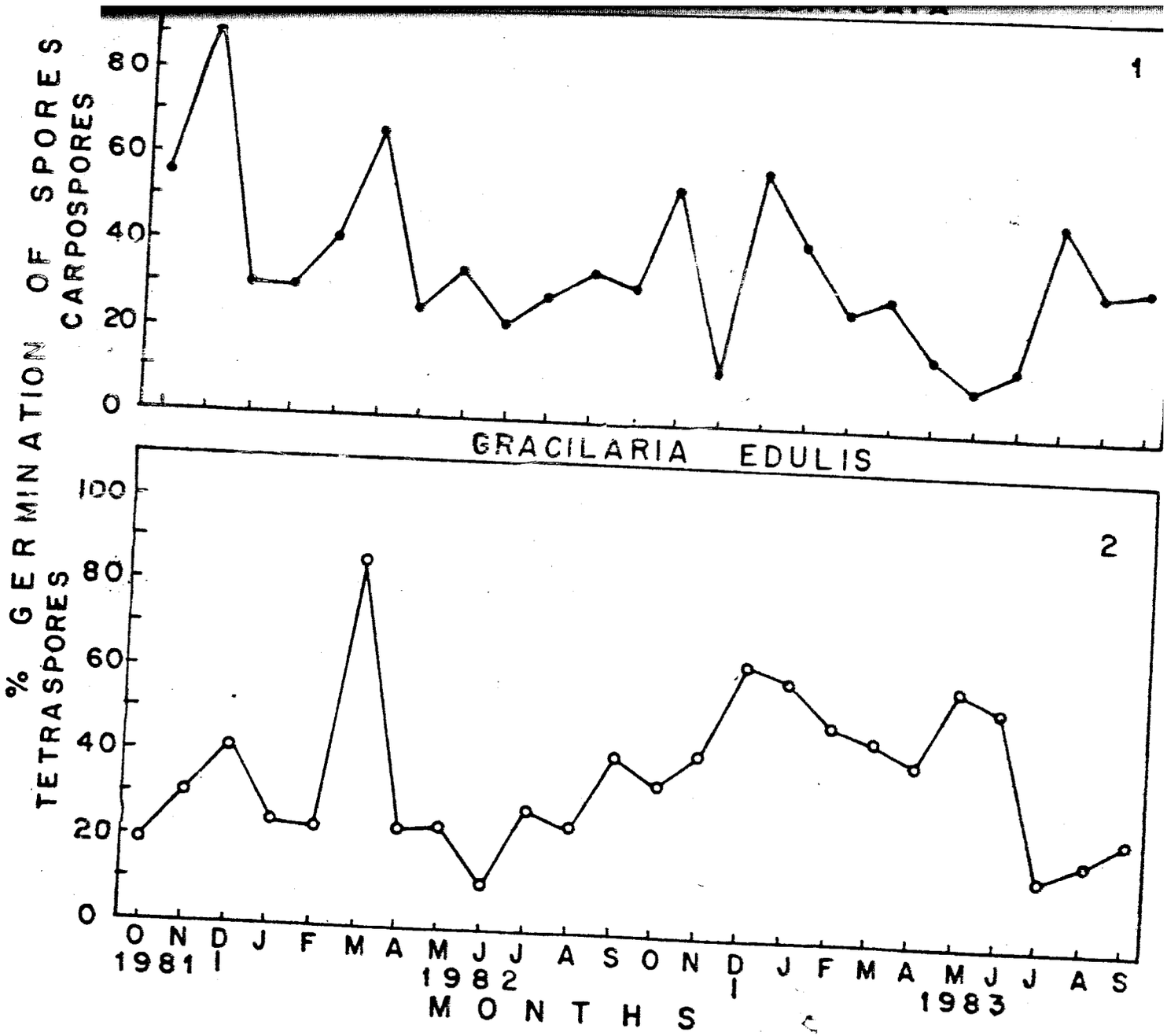

GRACILARIA EDULIS
% GERMINATION OF SPORES
CARPOSPORES
TETRASPORES
1
2
0
20
40
60
80
100
O N D J F M A M J J A S O N D J F M A M J J A S
1981
1982
1983
MONTHS

Figure No.43 Monthly variations in the germination of (1) carpospores of Gracilaria edulis (2) tetraspores of Hypnea musciformis.

FIGURE. 43. GRACILARIA EDULIS

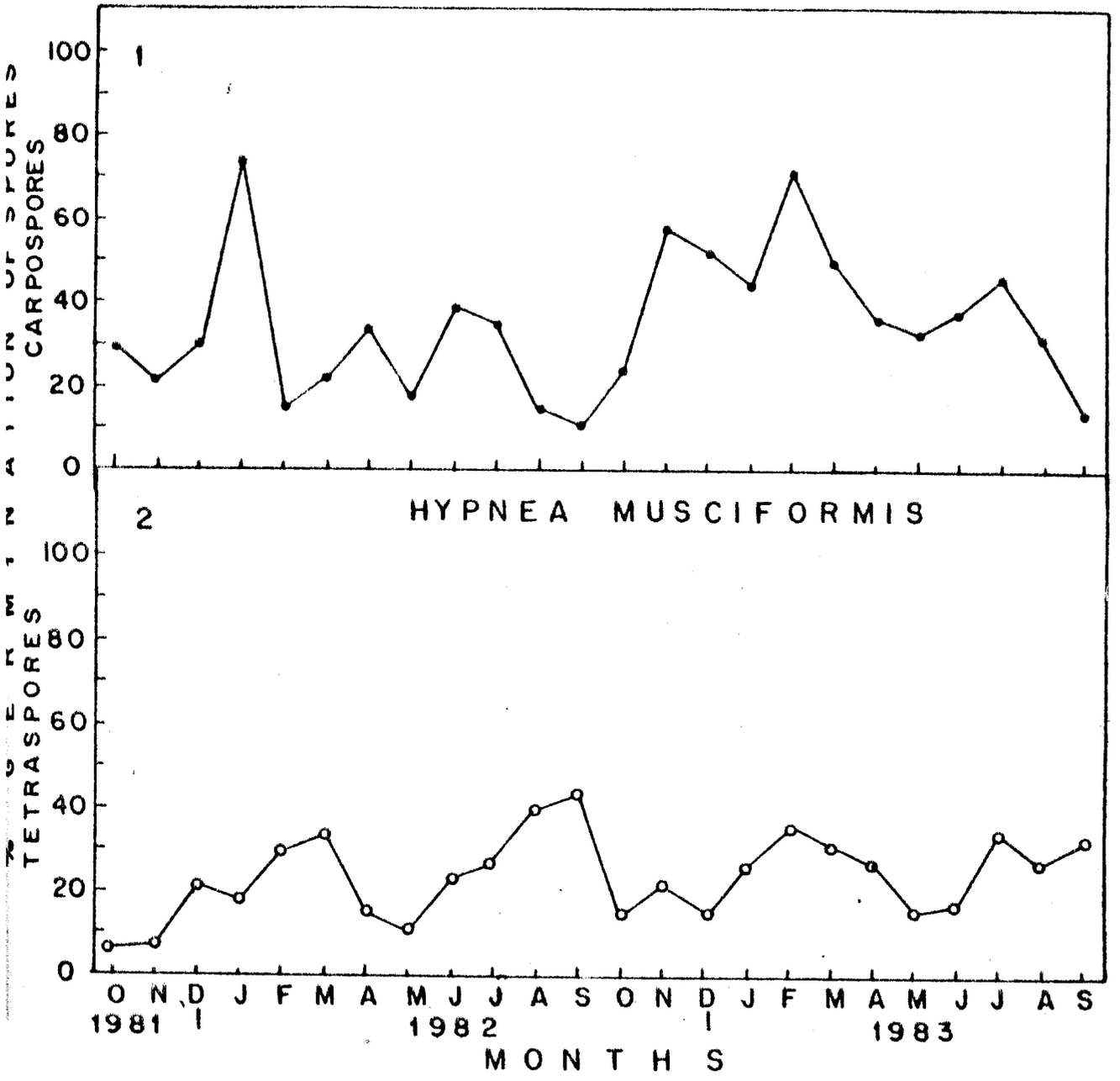


Figure No.44 Monthly variations in the germination of carpospores of Hypnea musciformis (i) from Kilakkarai and (ii) from Pudumadam.

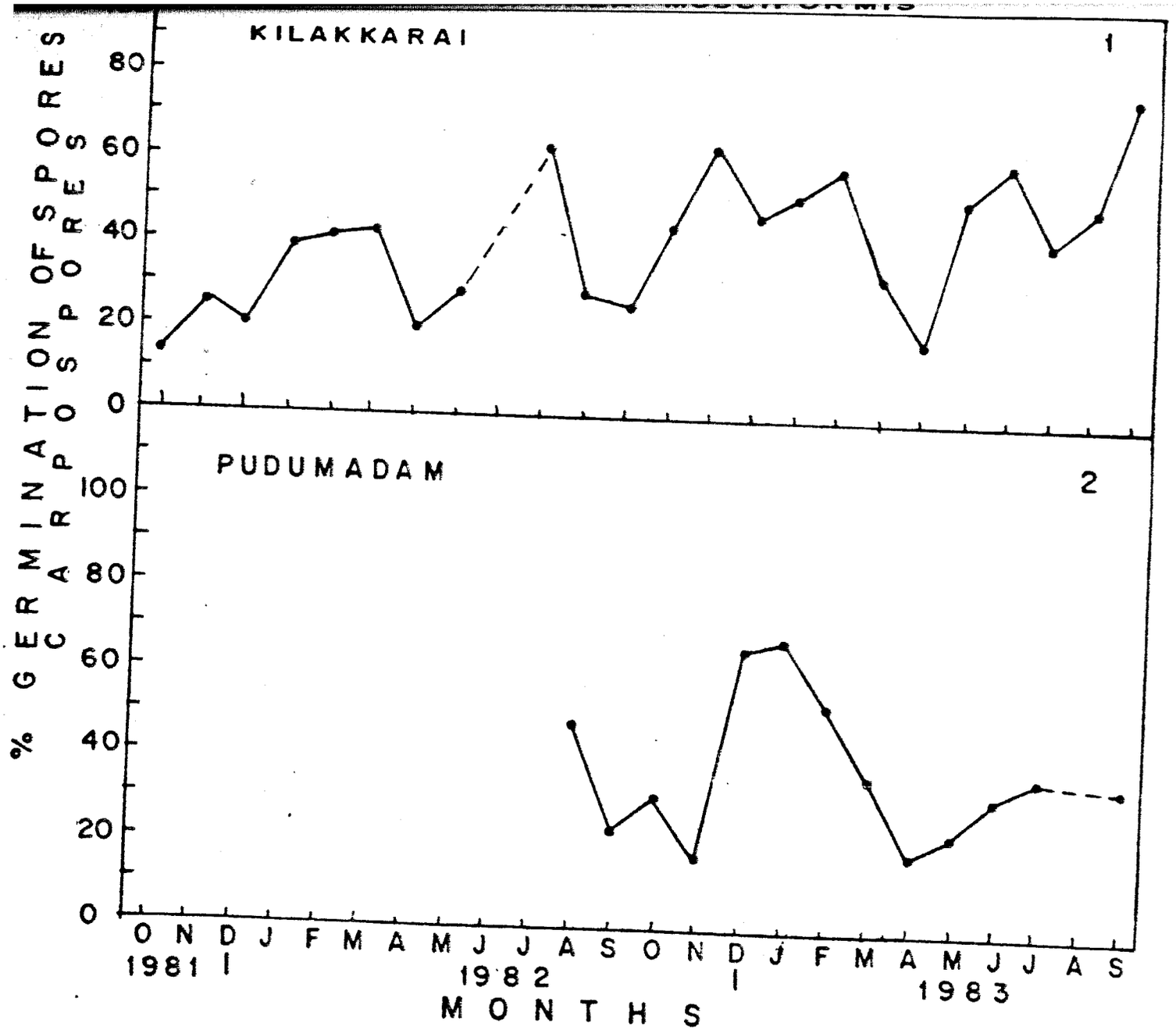

KILAKKARAI
1
PUDUMADAM
2
% GERMINATION OF SPORES
CARPOSPORES
0
20
40
60
80
100
O N D J F M A M J J A S O N D J F M A M J J A S
1981
1982
1983
MONTHS

Figure No.45 Effect of desiccation on spore germinat

(A) Germination of tetraspores in Gelidiella acerosa.

(B) Germination of tetraspore and carpospore in Gracilaria edulis.

(C) Germination of tetraspore and carpospore in Gracilaria edulis.

FIGURE_45. GERMINATION OF SPORES

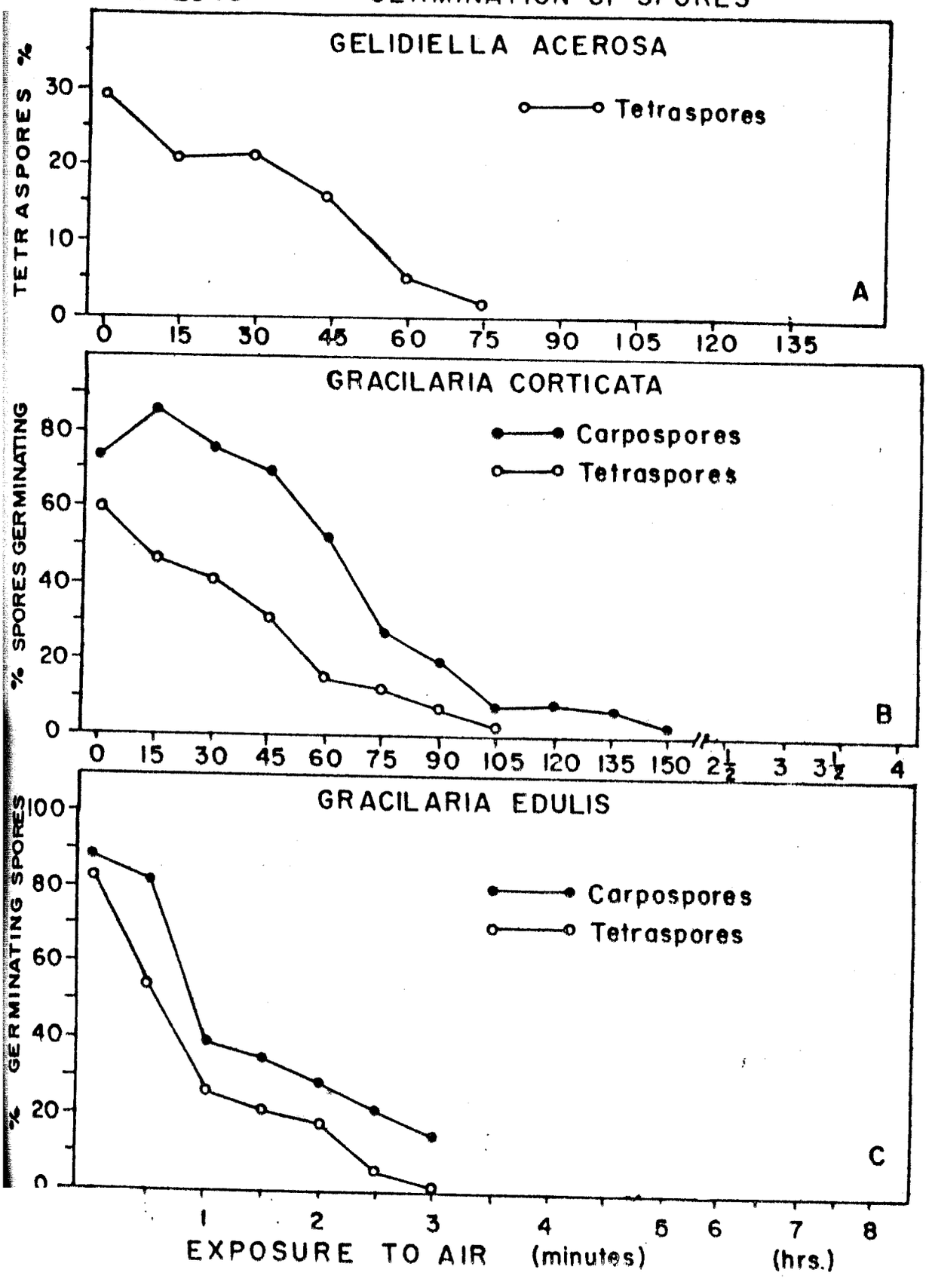
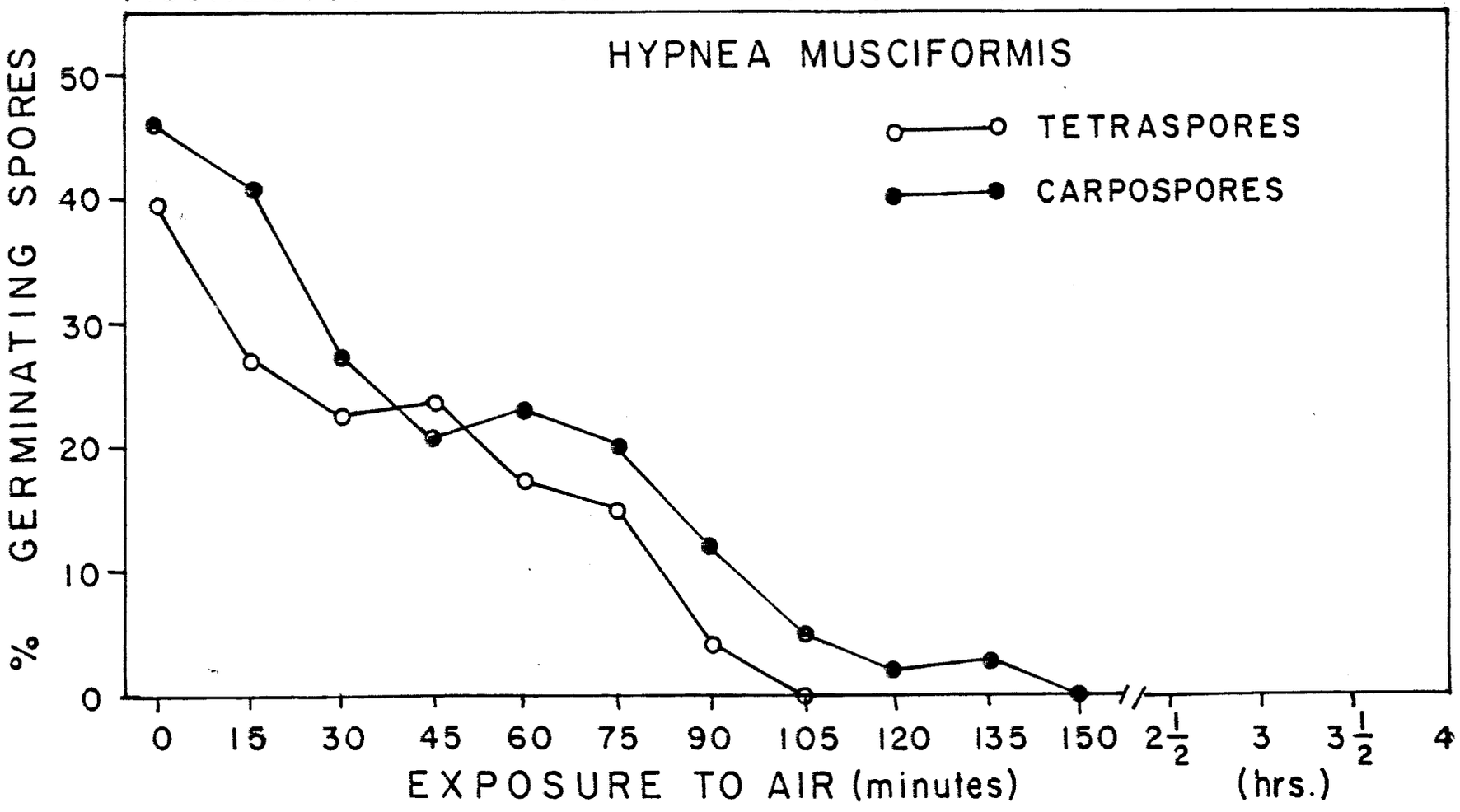


Figure No.46 Effect of desiccation on the germination of spores (tetraspores and carpospores) in Hypnea musciform

FIGURE-46. GERMINATION OF SPORES



to air upto 2½ to 3 hours (Fig.45C). Germination of spore was not seen in the frond exposed to 3 hours and 3½ hours in tetraspores and carpospores. In the experiments conducted with Hypnea musciformis, maximum spores germinated in the control, and the germination rate of tetraspores and carpospores was high in the controls which decreased with the increase in duration of exposure to air. Tetraspores did not germinate in the fronds exposed to 105 minutes and carpospore germination was not seen in the fronds exposed to more than 135 minutes (Fig. 46).

SALINITY

Germination of spores tested in different salinities for the four algal species is given in Figs. 47 - 48. Maximum germination of tetraspores of Gelidiella acerosa was observed at 20, 30 to 40 ‰ salinity. Tetraspores also germinated at 50, 60 and 10 ‰ S, but the intensity was low. There was no germination at 0 ‰ and 70 ‰ and above salinity. In the experiments conducted for Gracilaria corticata, Gracilaria edulis and Hypnea musciformis, tetraspores and carpospores did not germinate at 0 o/oo S. At 10‰S spores of the 4 algae germinated except the tetraspores of Hypnea musciformis. Germination rate increased at 20 o/oo and the highest rate of germination of spores could be seen at 30 o/oo S in Gracilaria corticata, Gracilaria

Figure No.47 Effect of salinity on (1) germinati of tetraspore in Gelidiella acerosa, (2) germination of tetraspore in Gra corticata (3) germination of carpos in Gracilaria corticata (4) germinati of tetraspore in Gracilaria edulis.

FIGURE - 47. GERMINATION OF SPORES

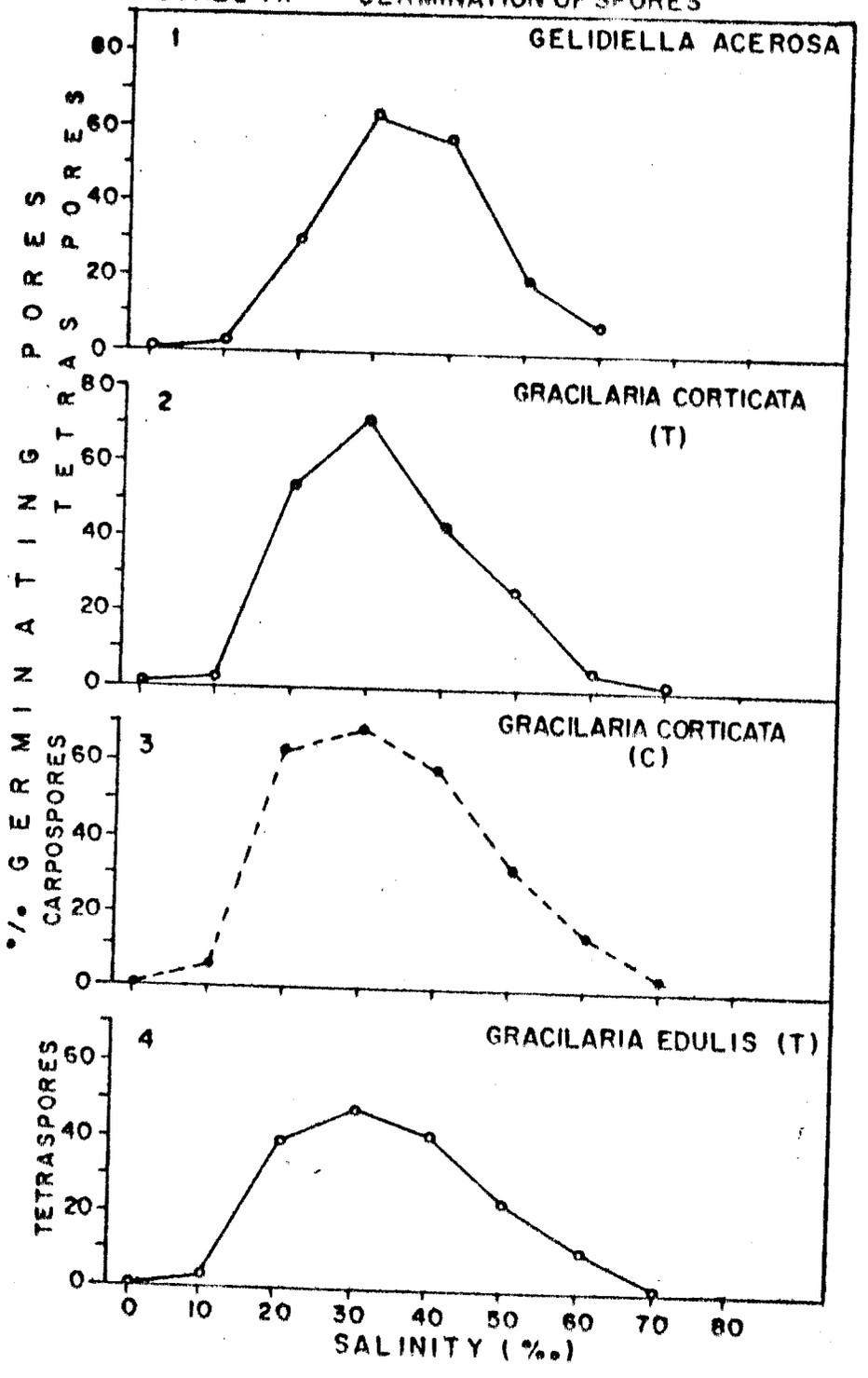


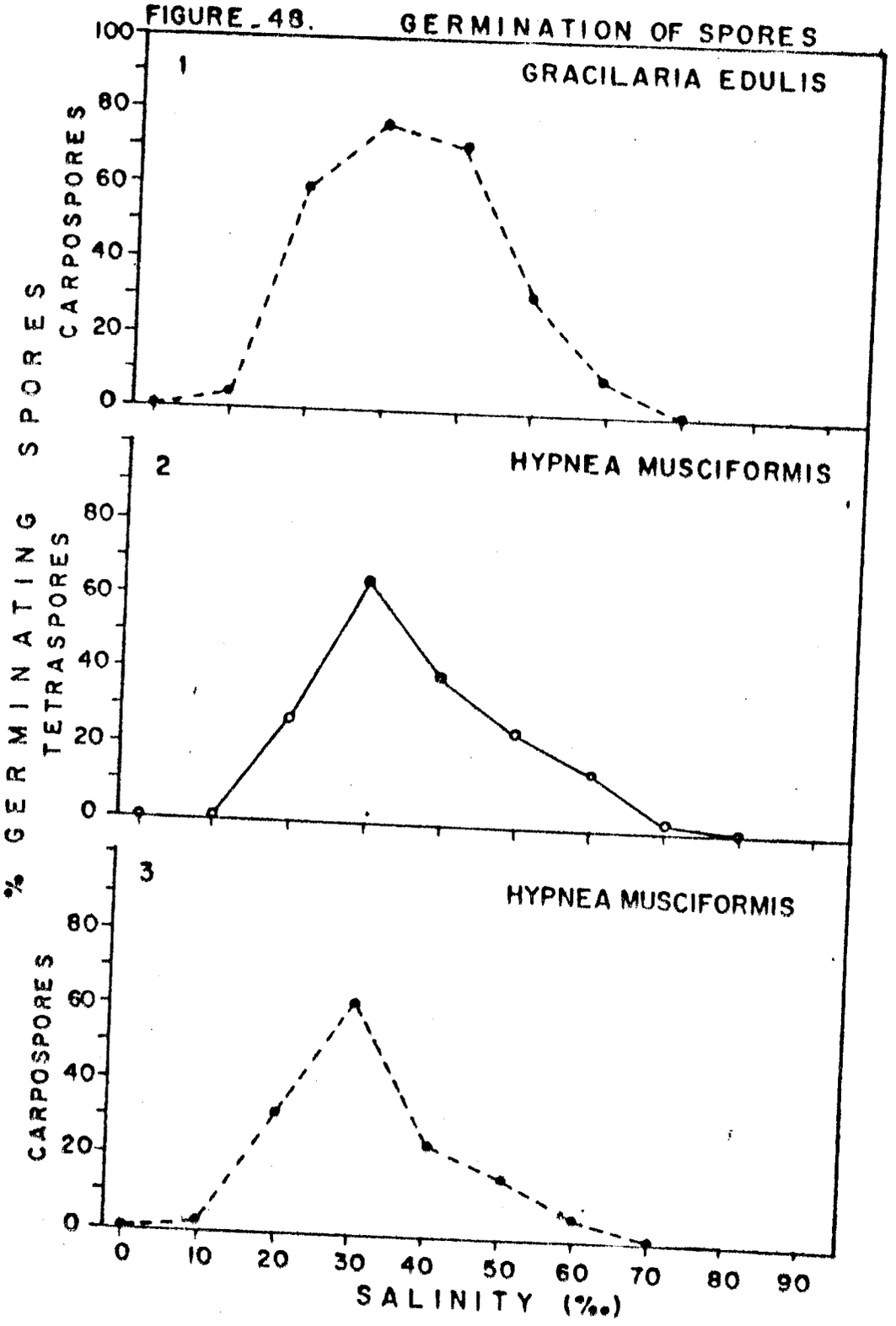
Figure No.48 Effect of salinity on the following:

(1) Germination of carpospore in *Gracilaria edulis*.

(2) Germination of tetraspore in *Hypnea musciformis*.

(3) Germination of carpospore in *Hypnea musciformis*.

FIGURE 48. GERMINATION OF SPORES



edulis and Hypnea musciformis, though high rate of tetraspore and carpospore germination was also seen at 20 o/oo and 40 o/oo S. Germination of spore was not seen above 70 o/oo S in Gracilaria corticata, 60 o/oo S in G. edulis and 70 o/oo S in tetraspore and 60 o/oo S carpospore of Hypnea musciformis.

TEMPERATURE

The experiments conducted in different temperatures, for the germination of spores in the four red algae has been represented in Figs. 49 - 50. Spores(tetraspores) of Gelidiella acerosa did not germinate in the fronds kept at -15 °, 0 ° C whereas spores germinated at 20 ° C and maximum rate of germination occurred at 30 ° C. Germination of spores decreased after 35 °C. Spores did not germinate at 45 °C and complete inhibition was seen at 50 °C. Spore germination tested for the tetraspore and carpospore of Gracilaria and Hypnea for the experiments conducted at 10 different temperatures (-15 °, 0 °, 5 °, 20 °, 25 °, 30 °, 35 °, 40 °, 45 ° & 50 °C) are given in Figs.49 & 50. The tetraspores and carpospores of Gracilaria corticata did not germinate at -15 °C, 0 ° and 5 °C. At 20 °C germination rate increased with maximum rate of germination occurring at 30 °C. At 25 ° and 35 ° C also germination rate was more or less high. But there was no germination

Figure No.49 Effect of temperature on the :

(1) Germination of tetraspores in Gelidiella acerosa.

(2) Germination of tetraspores in Gracilaria corticata.

(3) Germination of carpospores in Gracilaria corticata.

(4) Germination of tetraspores in Gracilaria edulis.

FIGURE - 49. GERMINATION OF SPORES

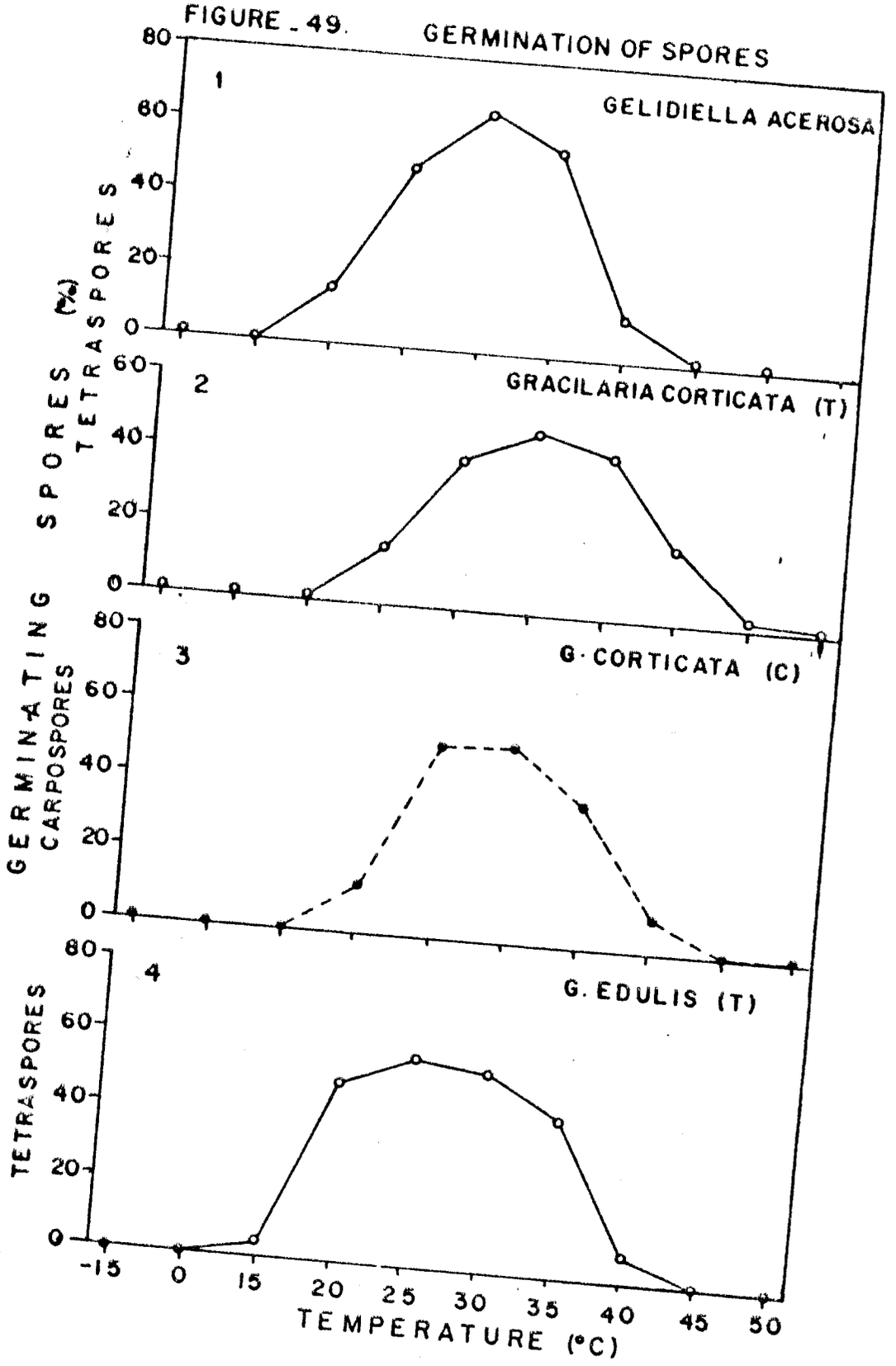


Figure No.50 Effect of temperature on the following:

(1) Germination of carpospores in *Gracilaria edulis*.

(2) Germination of tetraspores in *Hypnea musciformis*.

(3) Germination of carpospores in *Hypnea musciformis*.

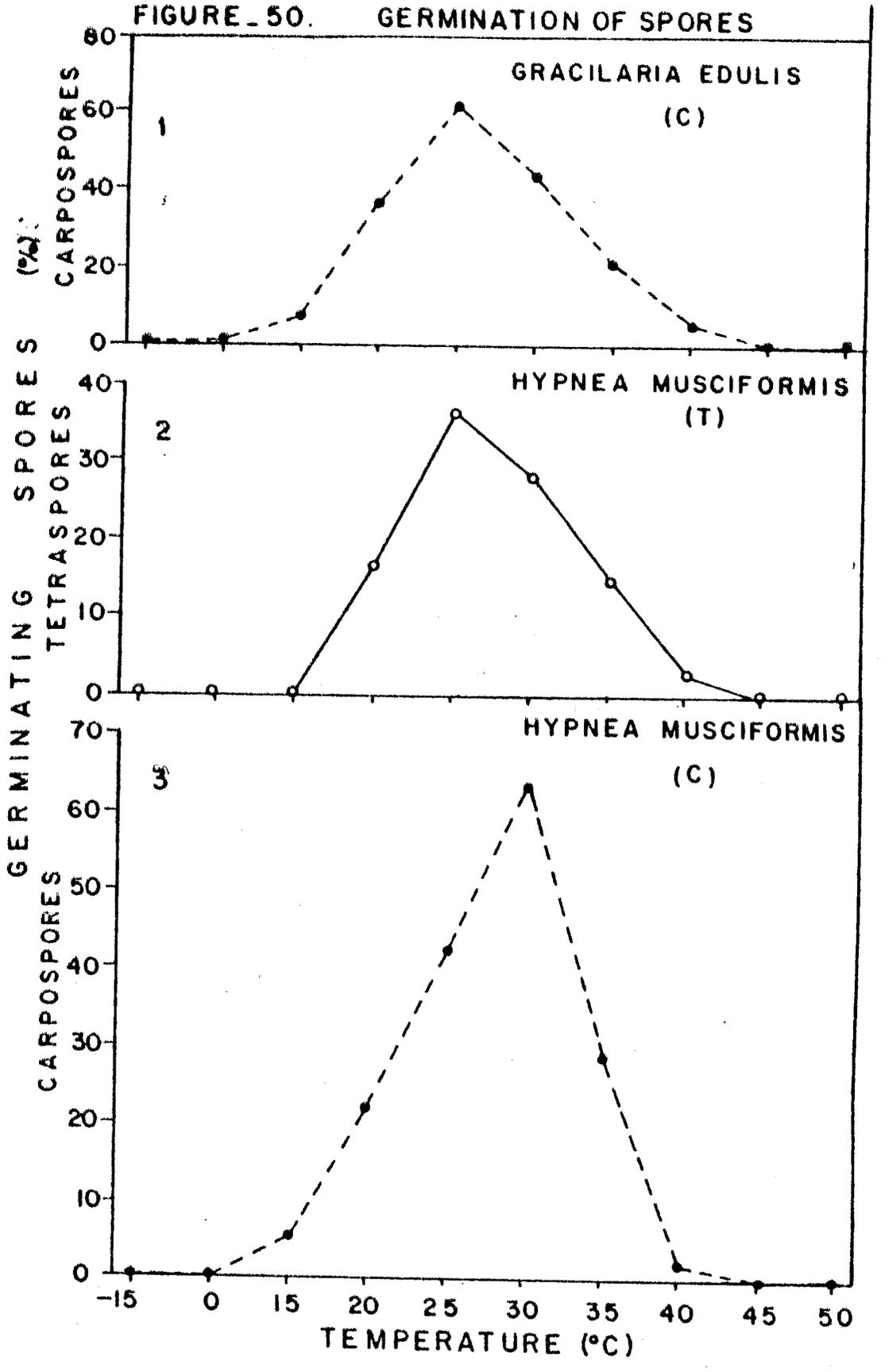


FIGURE_50. GERMINATION OF SPORES
GERMINATING SPORES (%)
CARPOSPORES
TETRASPORES
1
GRACILARIA EDULIS
(C)
2
HYPNEA MUSCIFORMIS
(T)
3
HYPNEA MUSCIFORMIS
(C)
0
10
20
30
40
50
60
70
80
-15
0
15
20
25
30
35
40
45
50
TEMPERATURE (°C)

at 45 °C in carpospore and at 50 °C for tetraspores. In the experiments conducted for Gracilaria edulis spores(tetraspores and carpospores) did not germinate in the fronds kept at -15 ° and 0 °C. Very few spores germinated at 5 °C and maximum rate of germination of spores was observed at 25 °C for both tetraspores and carpospores given in Figs.49 and 50. There was high rate of germination in the fronds exposed to 30 °C. After 35 °C, germination decreased and at 40 °C spores did not germinate and complete inhibition was seen at 45 ° and 50 °C. In the experiments conducted for Hypnea musciformis, tetraspores did not germinate in the fronds kept at -15 °, 0 ° and 5 °C whereas at 20 °C high germination was seen and maximum rate of germination was obtained at 25 °C and 30 °C. Germination of tetraspores decreased after 35 °C, at 40 °C spores did not germinate. The carpospores germinated at 5 °C. Germination of spores rapidly increased after 20 °C and maximum germination was observed at 30 °C. High values were also observed at 25 ° and 35 °C and very low at 40 °C. Spores did not germinate at 45 °and 50 °C.

LIGHT INTENSITY

The results of the experiments conducted at different light intensities (0, 500, 1000, 2000, 3000 and 4000 lux) for the four agarophytes to observe the germination rate in tetraspores and carpospores, are given in Figs.51 and 52. The germination rate in tetraspores of Gelidiella acerosa was high from 0 to 1000 lux light intensity and maximum rate of germination was observed at 200 lux light energy. Germination rate declined at 3000 lux and spores did not germinate at 4000 lux. (Fig.51.1). Similarly in the experiments conducted for Gracilaria corticata (Fig.51.2) the values obtained at 500 and 1000 lux were lower than that obtained in dark (0 lux). The rate of germination of spores was high between light intensities of 1000 and 3000 lux. In the carpospores the germination observed at 500 lux was less than that in dark but maximum germination of spores was observed between 500 and 3000 lux light intensities. In the germination of tetraspores of Gracilaria edulis (Fig.51.4) the rates of germination at 500 lux and 1000 lux were lower than the value obtained at 0 lux light intesity. Maximum germination was observed between 1000 lux and 3000 lux light levels. Germination rate decreased at 3000 lux. The rate of germination in the carpospores obtained is given in Fig.52.1. At 500 lux and 1000 lux the rates of germination

Figure No.51 Effect of light intensity on the follo

(1) Germination of tetraspores in Gelidiella acerosa.

(2) Germination of tetraspores in Gracilaria corticata.

(3) Germination of carpospores in Gracilaria corticata.

(4) Germination of tetraspores in Gracilaria edulis.

FIGURE _ 51

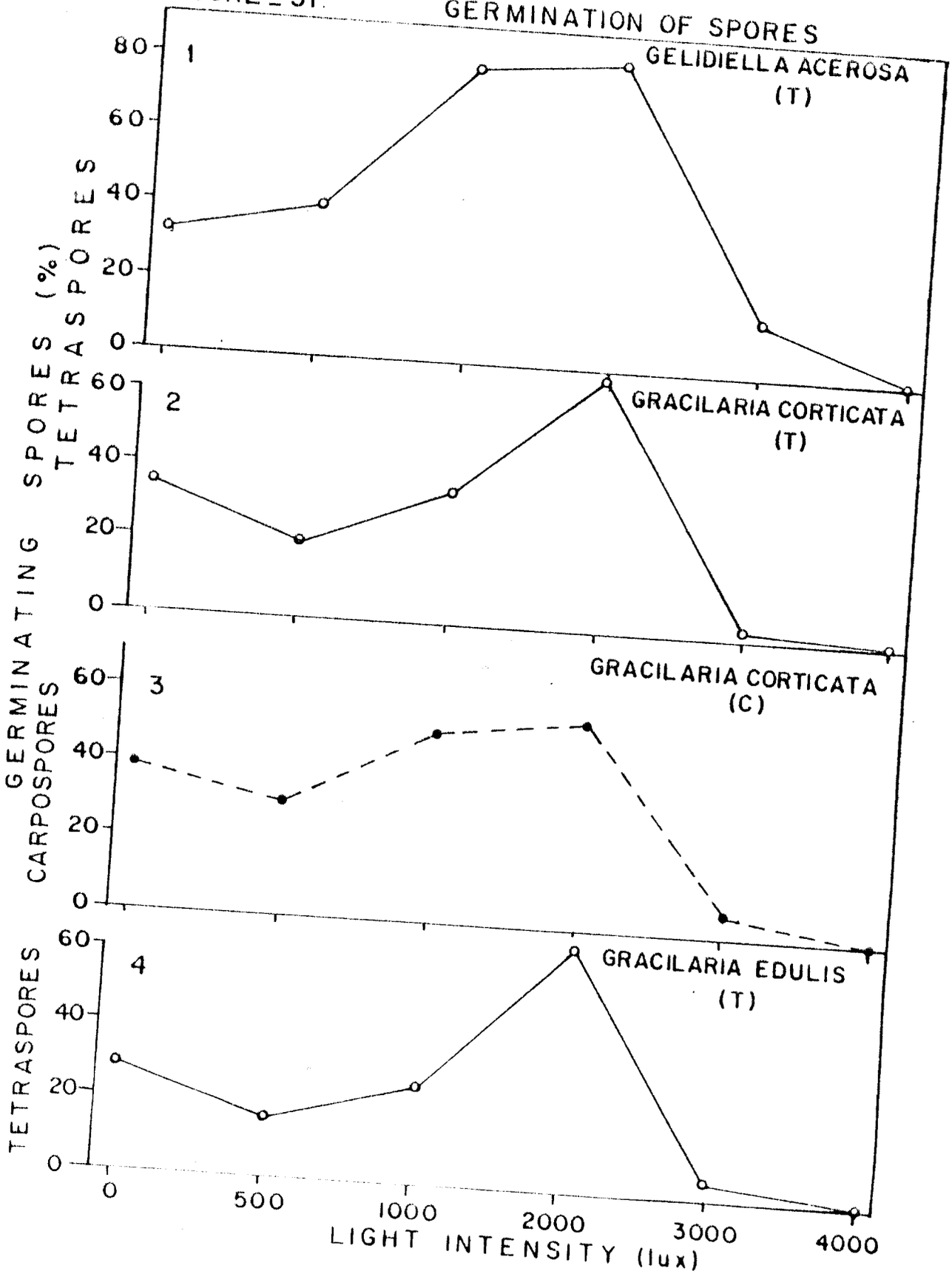

GERMINATION OF SPORES
1
GELIDIELLA ACEROSA
(T)
2
GRACILARIA CORTICATA
(T)
3
GRACILARIA CORTICATA
(C)
4
GRACILARIA EDULIS
(T)
GERMINATING SPORES (%)
TETRASPORES
CARPOSPORES
TETRASPORES
0
20
40
60
80
0
500
1000
2000
3000
4000
LIGHT INTENSITY (lux)

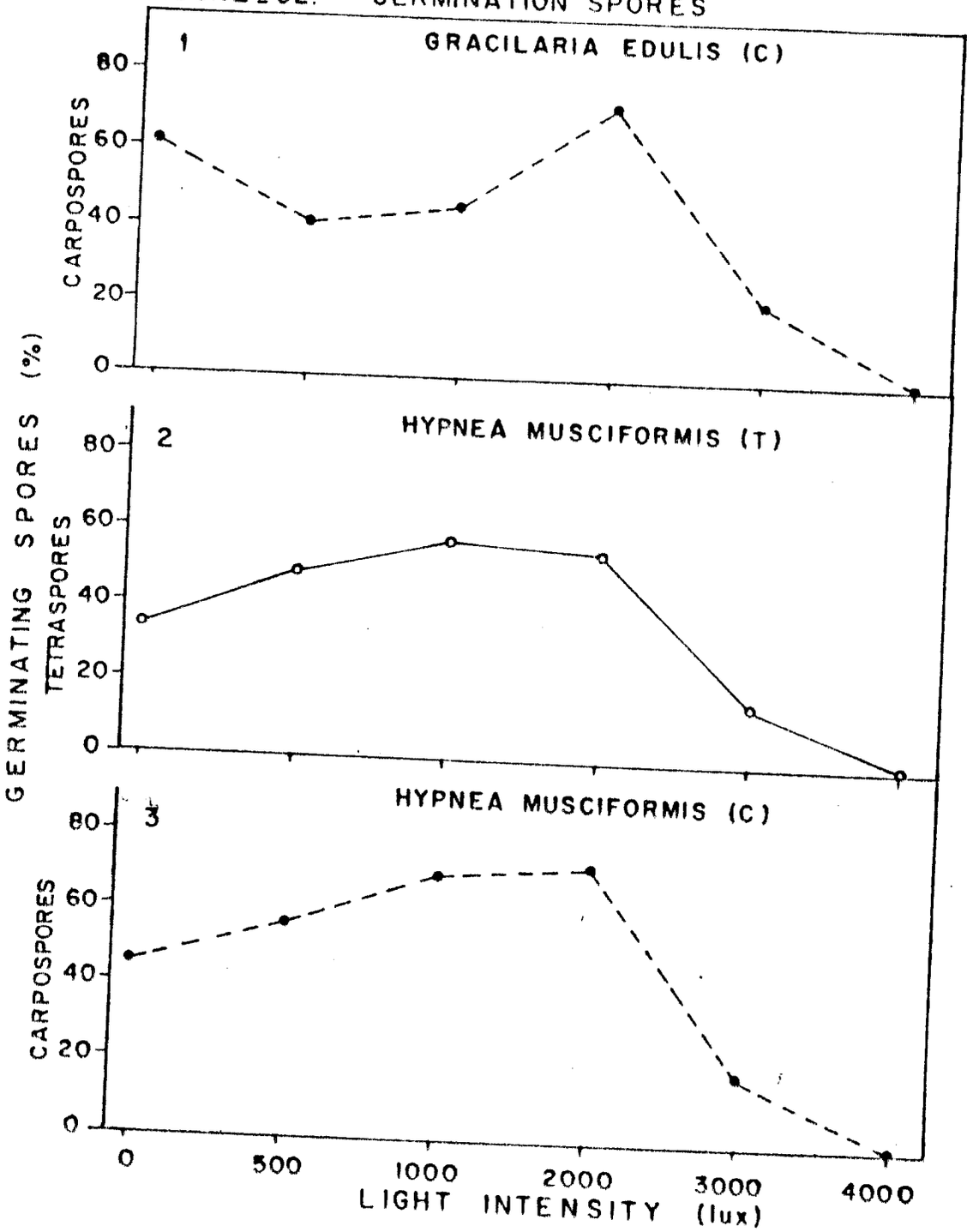
Figure No.52 Effect of light intensity on the follow

(1) Germination of carpospore in Gracil edulis.

(2) Germination of tetraspore in Hypnea musciformis.

(3) Germination of carpospore in Hypnea musciformis.

FIGURE_52. GERMINATION SPORES



are observed lower than at 0 lux light level and high spore germination was seen between 1000 to 3000 lux light level. After 3000 lux, the germination of spores decreased. In the similar manner in experiments conducted with ~~for~~ Hypnea musciformis (Figs.52.2 & 3), the rate of germination of tetraspores increased with the light level and high rate of germination was observed between 500 and 3000 lux light energies. The germination of carpospores also showed more or less the same trend (Fig.52.3) i.e. the rate of germination of carpospores of Hypnea musciformis increased with increase in the levels of light intensity and high rate of germination was observed between 500 and 3000 lux. In all these four algae studied there was no germination at 4000 lux light intensity.

PHOTOPERIOD

In the experiments conducted to study the combined effects of selected light intensity with duration of day length on the germination of spores of the four red algae studied are represented in the Figs.53.1, 53.2 & 53.3), The tetraspores of Gelidiella acerosa showed high rate of germination with duration in the increase in photoperiod of low light intensity (500 lux). The values in germination of spores at 4 : $\overline{20}$, 8 : $\overline{16}$ and 12 : $\overline{12}$ to 16 : $\overline{8}$ were low as compared to the fronds in dark (0 light intensity) but in (20 : $\overline{4}$ & 24 : $\overline{0}$) LD cycle higher rates of germination of spores was observed.

The fronds that were exposed to 2000 lux light intensity at different photoperiods, high germination was observed at 16 : $\overline{8}$ LD photoregimes, whereas at 20 : $\overline{4}$, 24 : $\overline{0}$ and 0 lux (0 : $\overline{24}$) spore germination was higher than during other photoperiods. In the fronds exposed to 4000 lux light level at different photoperiods, high spore germination was seen in dark (0 : $\overline{24}$). The tetraspores germinated, in the fronds kept at 4 : $\overline{20}$ LD cycle, but were less than that observed in 0 : $\overline{24}$ LD cycle. Germination of spores decreased after 4 : $\overline{20}$ LD cycle and spores did not germinate after 12 : $\overline{12}$ LD cycle (Fig.53.1).

The experiments conducted to study the germination of spores (tetraspore and carpospore) of Gracilaria corticata under different photoperiods are presented in Figs. 53.2 & 53.3. Higher spore germination was observed in dark (0 : $\overline{24}$ LD cycle) than with the fronds illuminated at 4 : $\overline{20}$ & 8 : $\overline{16}$ LD cycle (Fig.53.2). With the increase in the photoperiod, rate of germination of tetraspore increased after 16 : $\overline{8}$ LD cycle and high rate of germinating spores were observed at 24 : $\overline{0}$ LD cycle, in the fronds kept at 500 & 2000 lux light intensities. Fronds kept at light energy of 4000 lux, spores germinated in dark (0 light energy) and at 4 : $\overline{20}$ and 8 : $\overline{16}$ LD cycle. After 8 : $\overline{16}$ LD cycle germination decreased.

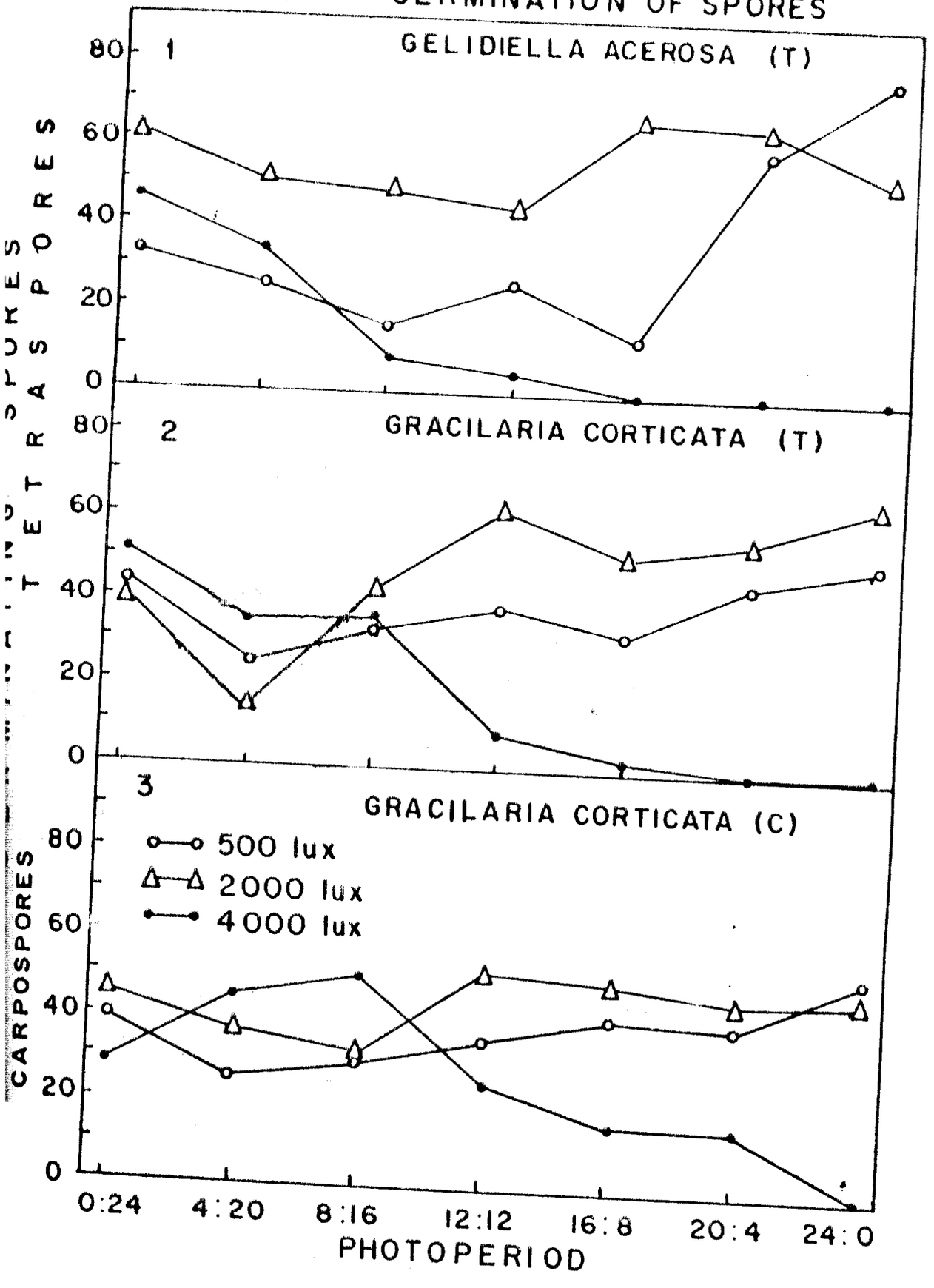
Figure No.53 Combined effects of light intensity and photoperiod (LD cycle) on the following:

(1) Germination of tetraspore in *Gelidiella acerosa*.

(2) Germination of tetraspore in *Gracilaria corticata*.

(3) Germination of carpospores in *Gracilaria corticata*.

FIGURE-53. GERMINATION OF SPORES



Spores did not germinate in the fronds kept under 20 : $\overline{4}$ and continuous illumination (24 : $\overline{0}$) (Fig.53.2).

Maximum carpospore germination was obtained in the cystocarpic fronds kept under continuous illumination of 500 lux light intensity (Fig.53.3). The values observed in the fronds kept in continuous dark were more or less higher than those values obtained in other photoperiods (4 : $\overline{20}$, 8 : $\overline{16}$, 12 : $\overline{12}$) and 16 : $\overline{8}$ LD cycles). With the light intensity of 2000 lux (medium light intensity), the cystocarpic thalli were tested under different photoperiods of 0 + $\overline{24}$, 4 + $\overline{20}$, 8 + $\overline{16}$, 12 + $\overline{12}$, 16 + $\overline{8}$, 20 + $\overline{4}$ and 24 + $\overline{0}$ LD cycles. High rate of germination was observed at continuous illumination (24 + $\overline{0}$ LD cycle) and also at 12 + $\overline{12}$ LD cycle). The fronds kept in dark (0 + $\overline{24}$) also showed high germination than those under 4 + $\overline{20}$ LD cycle. The cystocarpic thalli kept under high light intensity (4000 lux)and different LD cycles as treated above, germination was observed in 0 + $\overline{24}$ LD cycle, 4 + $\overline{20}$ and 8 + $\overline{16}$ LD cycles, but high rate of germination occurred at 0 + $\overline{24}$ LD cycle and slightly less values were obtained in 8 + $\overline{16}$ LD cycle (Fig. 53.3). Germination was not found at 24 + $\overline{0}$ LD photoregime.

Figure No.54 Combined effects of light intensity and LD cycle on :

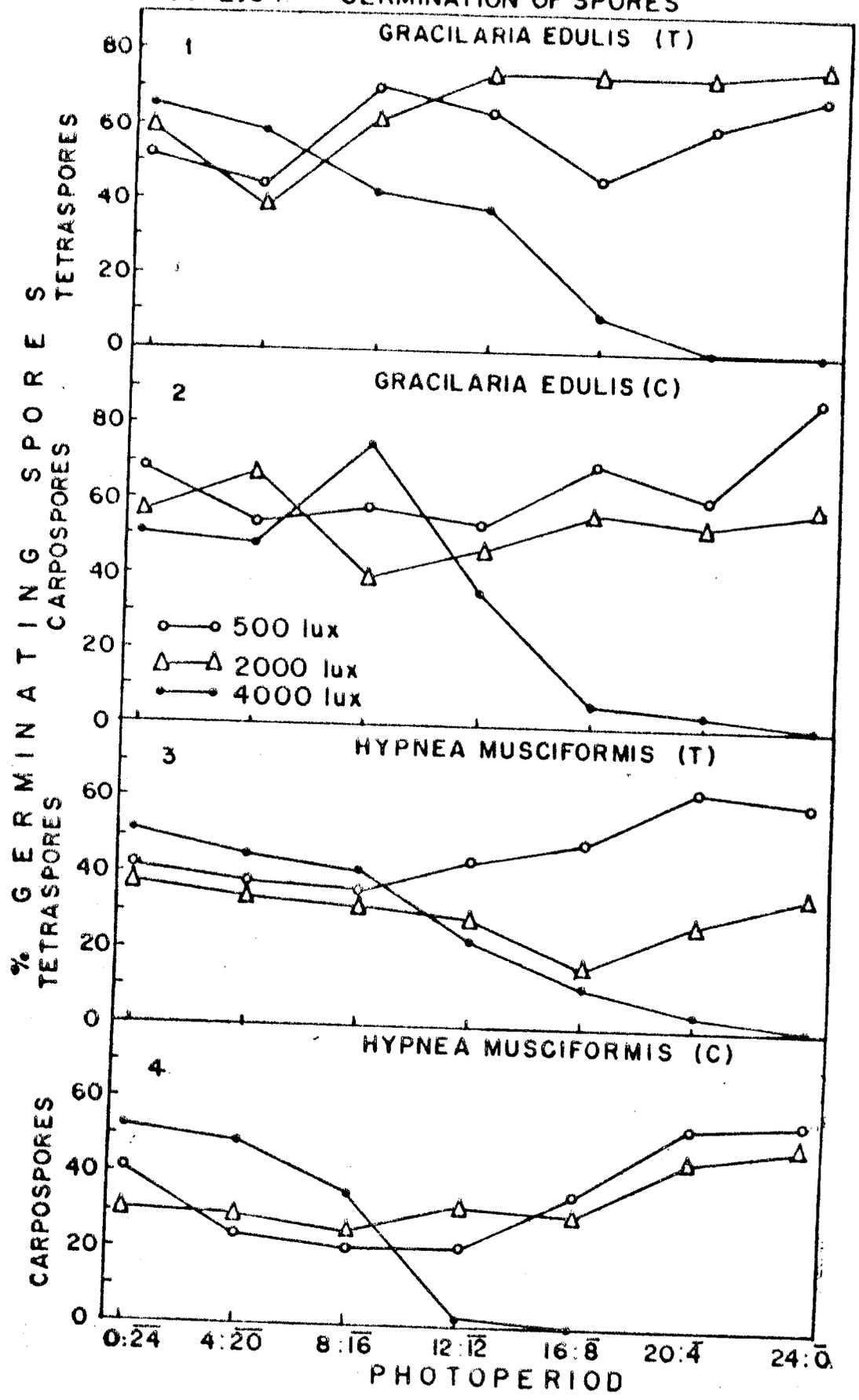
(1) Germination of tetraspore in Gracilaria edulis.

(2) Germination of carpospores in Gracilaria edulis.

(3) Germination of tetraspore in Hypnea musciformis.

(4) Germination of carpospore in Hypnea musciformis.

FIGURE. 54 GERMINATION OF SPORES



The trend was also similar in Gracilaria edulis for germination of tetraspores and carpospores which was seen in dark as well as in continuous illumination of low light intensities of 500 and 2000 lux and in high light energy of 4000 lux. Spores germinated in dark and the germination decreased with increase in the photoperiod of 4000 lux light intensity. Tetraspores did not germinate at 20 : $\overline{4}$ and 24 : $\overline{0}$ LD cycles, while in carpospores high rate of germination was observed at 8:$\overline{16}$ LD cycle (Fig. 54.2).

In Hypnea musciformis also similar trend was observed. Figs. 54.3 and 54.4 give the trend observed for the germination of tetraspores and carpospores at three different light intensities (500, 2000 and 4000 lux). Tetraspores and carpospores showed maximum germination at continuous illumination of low and medium light intensities but germination of spores observed in dark were also more than that seen at 4.$\overline{20}$ and 8:$\overline{16}$ to 16:$\overline{8}$ LD photoperiods. After 16.$\overline{8}$ LD cycle germination increased. The experiments conducted at high light intensity of 4000 lux, maximum germination of spores was observed in dark (0.$\overline{24}$ LD cycle) and the germination observed in 4.$\overline{20}$ and 8:$\overline{16}$ LD cycle, the values of which were lower than in 0.$\overline{24}$ LD cycle. Carpospores germinated upto 12:$\overline{12}$ photoperiod and at 16:$\overline{8}$ onwards carpospores

by walls perpendicular and paralell to form a multicellular disc or mass of cells from which an adult thallus develops. This type of germination is described as 'Dumontia' type.

4.7 SEASONAL CHANGES IN THE HYDROGRAPHICAL PARAMETERS :

The data collected from October 1981 to June 1983 on the atmospheric temperature, surface sea-water temperature, surface sea-water temperature, salinity, pH and dissolved oxygen of sea water in the three collection localities namely Thonithurai, Pudumadam and Kilakarai are presented in Figs. 55 - 57. During the period of this investigation the atmospheric temperature varied from 25.5 to 30.4 °C ; 26.0 to 31.5 °C and 26.4 to 32.1 °C, the sea water temperature from 25.8 to 30.7 °C, 26.0 to 30.7 °C, 26.0 to 30.7 °C, 26.4 to 31.9 °C ; salinity from 28.28 to 35.77 o/oo, 30.62 to 35.59 o/oo and 30.59 to 36.25 o/oo S and dissolved oxygen from 3.34 to 6.14 ; 3.55 to 5.69 and 2.67 to 6.33 ml/l at Thonithurai, Pudumadam and Kilakarai respectively. The pH of the sea-water varied only from 8.0 to 8.7.

Figure No.55 - Seasonal variations in the selected environmental parameters at the 3 localities of collection.

(e.g. Atmospheric temperature, surface-seawater-temperature, salinity, dissolved oxygen, and pH of the seawater in the collection localities) at Thonithurai (Station I)

FIGURE - 55 THONITHURAI (station I)

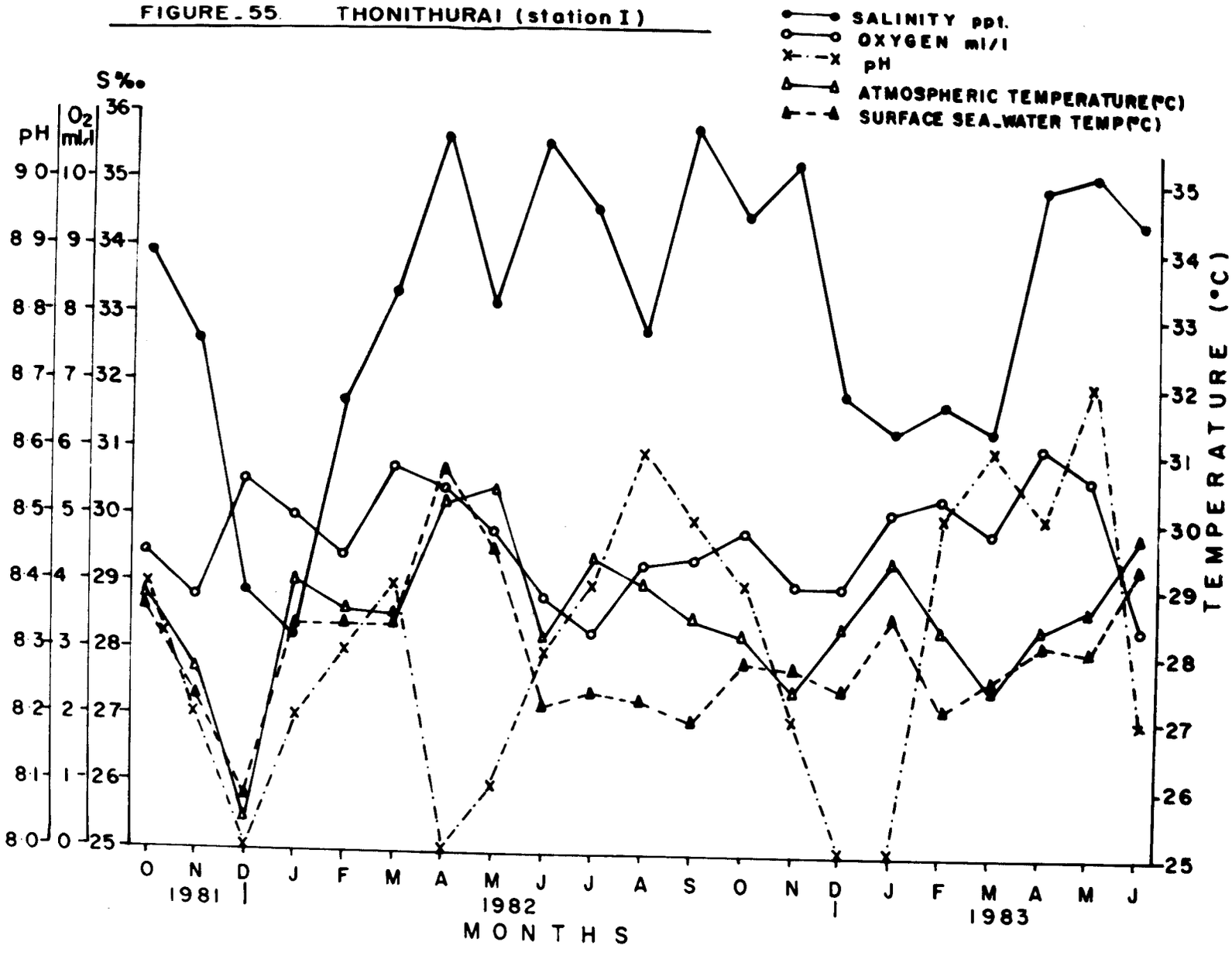


Figure No.56 Seasonal variations in the environmental parameters at Station II (Pudumadam).

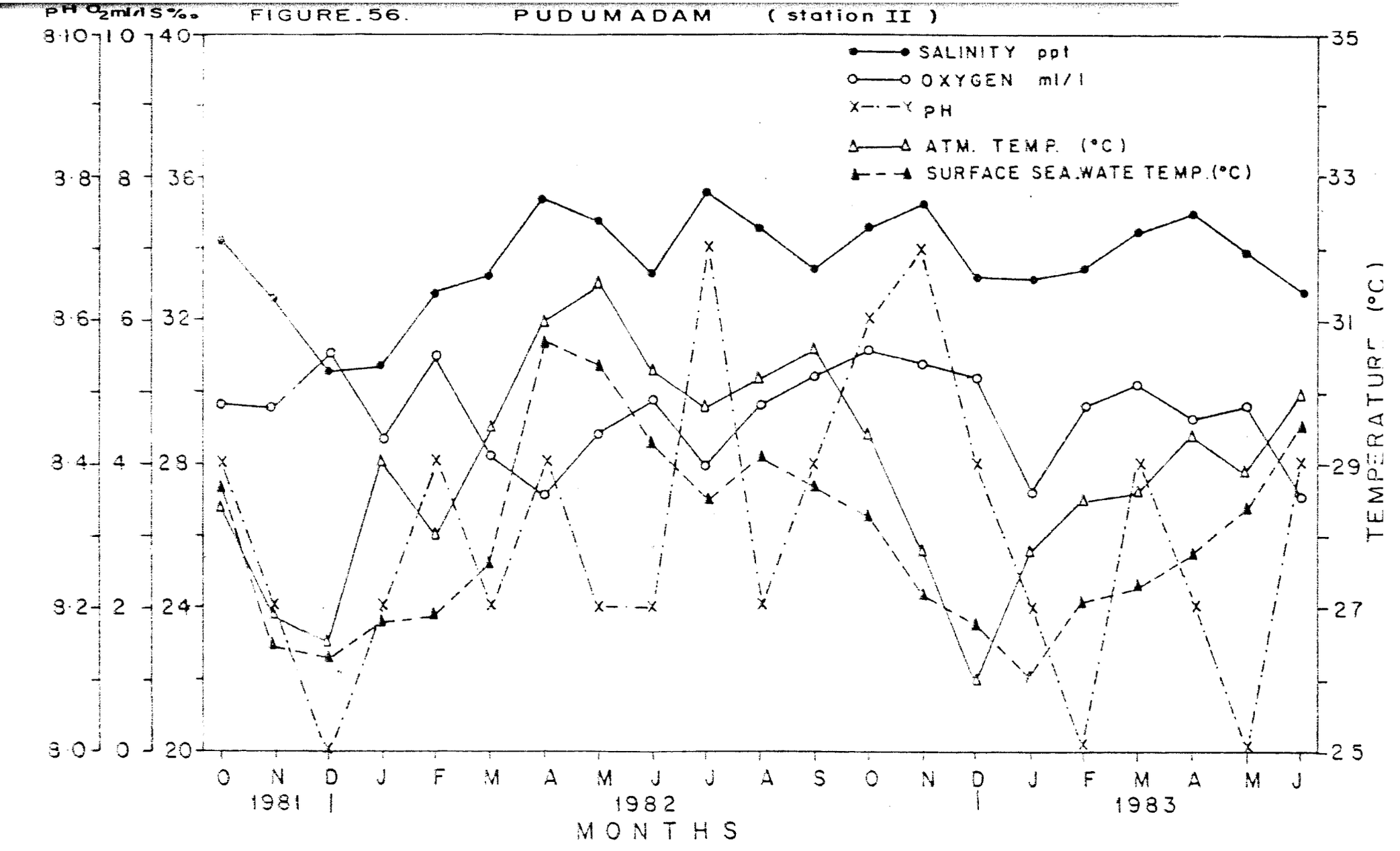
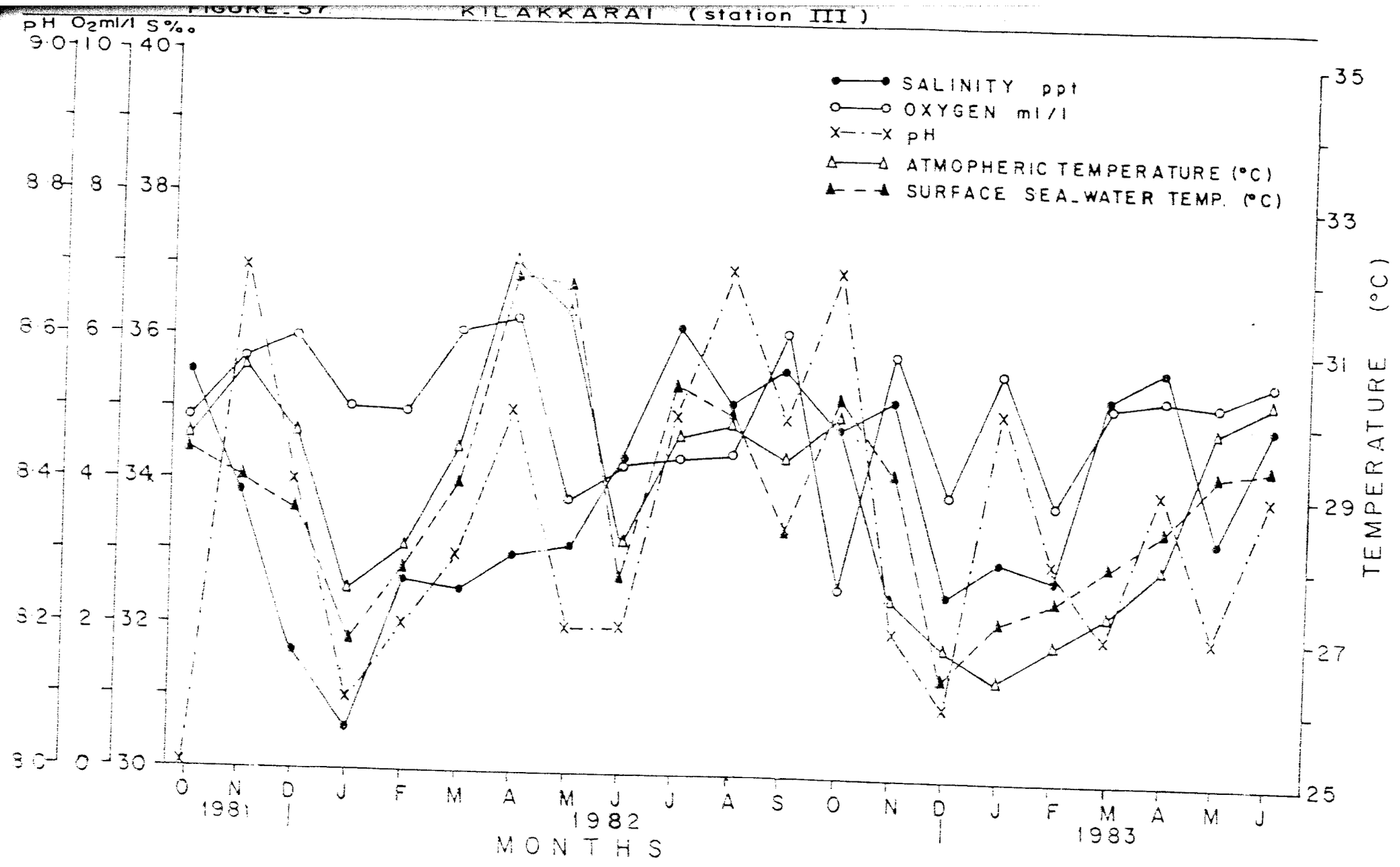


FIGURE.56. PUDUMADAM (station II)
pH
O2ml/l
S‰
SALINITY ppt
OXYGEN ml/l
pH
ATM. TEMP. (°C)
SURFACE SEA.WATE TEMP.(°C)
TEMPERATURE (°C)
8·0
8·2
8·4
8·6
8·8
8·10
0
2
4
6
8
10
20
24
28
32
36
40
25
27
29
31
33
35
O N D J F M A M J J A S O N D J F M A M J
1981
1982
1983
MONTHS

Figure No.57 Seasonal variation in the environmental parameters at Station III (Kilakkarai).

FIGURE-37 KILAKKARAI (station III)



CHAPTER - 5

DISCUSSION

In the present study, data were collected on fruiting behaviour and sporulation of four economically important red algae growing along the Mandapam coast namely Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis. Experiments were conducted with these algae under laboratory conditions to find out the variations in spore production in different months of the year and to know the diurnal periodicity in spore shedding and environmental factors affecting the spore output.

As reported earlier from Mandapam area for Gelidiella acerosa (Umamaheswara Rao, 1973 a; Thomas et al., 1975 a; Rama Rao and Subbaramaiah, 1979; Subba Rao, 1979 and Chennubhotla et al., 1979), Gracilaria corticata (Umamaheswara Rao, 1972 b and Chennubhotla et al., 1979), and Gracilaria edulis (Umamaheswara Rao, 197 and Chennubhotla et al., 1979) in the present investigation also populations of these red algae and also Hypnea musciformis were observed throughout the year in the vicinity of Mandapam.

FRUITING BEHAVIOUR

At Veraval the tetrasporophytic plants of Gelidiella acerosa were seen in the population during April - May and October - November (Sreenivasa Rao, 1974). The tetrasporophytes in the population of Gelidiella acerosa growing at Rameswaram remained continuously for 7 to 9 months from February to October and

in general maximum number of plants with stichidia occurred in the population after the two peak growth seasons in an year (Umamaheswara Rao, 1973 a). In the Gelidiella acerosa plants growing at Pudumadam, tetrasporic plants occurred in all the months of the year except in July. Minimum number of stichidia with mature tetrasporangia was found in August and September.

Similarly the number of stichidia per plant was low again in February and March. In other months of the year fertile ramulii were more, indicating that peak reproductive activity occurred between April and June and between October and December (Umamaheswara Rao, 1974). At Kilakarai plants of Gelidiella acerosa showed peak reproductive period of tetrasporic plants in June (Thomas et al., 1975 b), whereas in Gelidiella acerosa growing at Rameswaram the number of stichidia per plant showed a maximum in January and the maximum percentage of tetrasporic plants was observed in June. A second lower maximum in the number of stichidia per plant was observed in August. The reproductive capacity of the population which combined both these features showed two maxima, one in January and another in June. The tetrasporic plants occurred only from August to January in a year (Rama Rao et al., 1976). As reported in other geographical areas (Chihara and Kamura, 1963)

sexual plants were not encountered in these studies. But in the present study tetrasporic plants were found throughout the year in the populations of Gelidiella acerosa growing at Kilakkarai as previously observed at Pudumadam by Umamaheswara Rao (1974). Cystocarpic plants in Gelidiella acerosa were not encountered in the present investigation as reported from India by Sreenivasa Rao, (1969) and Umamaheswara Rao (1973 a) and in other geographical areas by Chihara and Kamura (1963).

In Gracilaria corticata growing at Veraval, tetrasporic plants occurred almost throughout the year while sexual plants occurred seasonally (Oza, 1979). But in Gracilaria corticata growing at Mandapam (Umamaheswara Rao, 1976) and Visakhapatnam (Subba Rangaiah, 1978) both tetrasporic and cystocarpic plants occurred in all months of the year. Similarly asexual and female plants were observed throughout the year in the population of Gracilaria corticata occurring at Pudumadam.

In Gracilaria edulis growing at Rameswaram, tetrasporophytes occurred for eleven months in an year and cystocarpic plants were seen only in the month of January(Umamaheswara Rao,1973 b) But in Gracilaria edulis growing at Thonithurai, tetrasporic and cystocarpic plants occurred in the population in all months of the year. At Visakhapatnam coast tetrasporophytes

and carposporophytes in the population of Hypnea musciformis occurred in all the months of the year (Subba Rangaiha, 1978). Though the tetrasporic plants were observed throughout the year in Hypnea musciformis growing at Pudumadam, cystocarpic plants were seen only for some months in the population at Pudumadam and Kilakarai. P.O. [This agrees with the findings of Rama Rao (1977 b) for Hypnea musciformis growing at Pudumadam, cystocarpic plants were seen only for some months in the population at Pudumadam and Kilakarai.] This agrees with the findings of Rama Rao (1977 b) for Hypnea musciformis growing at Veraval and Hypnea valentiae growing at Pamban and Krusadai Island.

Spore Shedding :

Maximum and minimum values obtained on spore production during the entire period of this study are given below to show the range in the quantity of spores liberated in Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis.

Table (9)

Maximum and Minimum Values of Spore Output :

(expressed as g. fr. wt. per month)

Algae	Tetraspores/g. fr.wt./month		Carpospores/g. fr.wt./month	
	Minimum	Maximum	Minimum	Maximum
Gelidiella acerosa	5,744	3,89,793	-	-
Gracilaria corticata	8,181	92,277	8,086	4,87,178
G. edulis	2,135	1,09,565	28,652	3,27,833
Hypnea musciformis	2,662	5,04,953	2,814	6,46,385

Studies that have been conducted on sporulation of some red algae growing at Mandapam area and other localities of Indian coast are discussed below :

In Gelidiella acerosa a maximum output of 10,000 tetraspores per plant was observed (Sreenivasa Rao, 1969). The tetraspore production varied from about 5000 to 10,000 spores/g. fresh wt./day in the plants collected from Pudumadam (Umamaheswara Rao, 1974 a). The tetraspore shedding in Gracilaria corticata occurring at Mandapam ranged from 84,000 to 3,98,000 spores/g. fresh wt./day and carpospores from 1183 to 2374 spores per cystocarp per day (Umamaheswara Rao 1976). A maximum carpospore liberation of 8,66,700 spores/plant was found

by Mohan Joseph and Krishnamurthy (1977) in Gracilaria corticata collected from Mandapam.

In Gelidium pusillum and Pterocladia heteroplatos growing at Visakhapatnam coast, tetraspore output ranged from 1,149 to 10,78,505 and carpospores from 1,176 to 6,99,943 in Gelidium pussilum and 1,427 - 7,94,055 tetraspores 39,966 - 1,67,040 carpospores/g. fresh wt./day in Pterocladia heteroplatos (Kaliaperumal 1979).

In Gracilaria corticata occurring at Mandapam, tetraspore shedding ranged from 84,000 to 3,98,000 spores/g. fresh wt./ day and carpospores from 1,183 to 2,374 spores/cystocarp/day (Umamaheswara Rao, 1976). A maximum carpospore liberation of 8,66,700 spores/plant was found by Mohan Joseph and Krishnamurthy (1977) in G. corticata collected from Mandapam. The carpospore output per plant varied from 6,919 to 6,49,873 from plants of Gracilaria edulis collected from Krusadai Island near Mandapam (Rama Rao and Thomas, 1974).

In Gracilaria millardetii, Krishnamurthy (1967) recorded maximum output of 68,500 tetraspores and 42,782 carpospores per plant. Oza and Krishnamurthy (1968) observed a maximum liberation of 70,000 carpospores per plant in Gracilaria verrucosa growing at Kuda near Bhavanagar in Gujarat. In

Hypnea valentiae from Mandapam maximum number of 3,14,944 tetraspores and 7,01,607 carpospores were released (Rama Rao, 1979). Subba Rangaiah (1978) collected data on tetraspore and carpospore outputs in the four members of Gigartinales namely Gracilaria corticata, G. textorii, Gracilariopsis sjoestedtii and Hypnea musciformis growing at Visakhapatnam coast and maximum spore output was found on first day. The tetraspore output ranged from 13,665 to 12,30,380 spores/g. fresh wt./day and carpospore output varied from 280 to 6807 spores/cystocarp/day among the four red algae. In Gelidiopsis variabilis growing at Visakhapatnam coast shedding of tetraspores from stichidia was observed for 3-4 days with maximum discharge of spores on the first day (Kaliaperumal and Umamaheswara Rao, 1982). The quantity of spores liberated on the first day varied from a low value of 20 spores to a maximum of 2,60,940 spores per gram fresh weight of the plant.

The carpospore output per plant varied from 6919 to 6,49,873 in Gracilaria edulis collected from Krusadai Island near Mandapam (Rama Rao and Thomas, 1974).

The present estimation given above in Table (9) are based on total number of spores released per month. The above figures reveal that the spore shedding capacity is very high in the four algae studied. The values obtained for tetraspore output in Gelidiella acerosa in the present investifation are higher than that obtained for G. acerosa growing in the tidalpools at Veraval (Sreenivasa Rao,1969). The tetraspore production varied from about 5000 to 10,000 spores/g fresh wt/day at Pudumadam (Umamaheswara Rao,1974 a). The spore output estimated in the four red algae can be compared with the values reported for Gelidium amansii (Suto, 1959 b), Gelidium pussilum and Pterocladia heteroplatos (Kaliaperumal, 1979), Gracilaria corticata (Umamaheswara Rao, 1976; Mohan Joseph and Krishnamurthy, 1977 and Subba Rangaiah, 1978), G. edulis (Rama Rao and Thomas, 1974), G. millardetii (Krishnamurthy, 1967), G. textorii (Subba Rangaiah, 1978), G. verrucosa (Oza and Krishnamurthy, 1958), Hypnea valentiae (Rama Rao, 1979), Hypnea musciformis and Gracilariopsis sjoestedtii (Subba Rangaiah, 1978) and Gelidiopsis variabilis (Kaliaperumal and Umamaheswara Rao, 1983).

In general, maximum shedding of spores was seen on the first day in the four red algae (Tables 1-8) and it agrees with the results obtained for Gelidium amansii (Suto, 1950 a),

Antithamnion plumula (Boney, 1960), Gracilaria edulis (Rama Rao and Thomas, 1974), G. corticata (Mohan Joseph and Krishnamurthy, 1977 and Subba Rangaiah, 1978), G. textorii, Gracilariopsis sjoestedtii and Hypnea musciformis (Subba Rangaiah, 1978) and Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis (Kaliaperumal, 1979 and Kaliaperumal and Umamaheswara Rao, 1982). Rhythmic liberation of carpospores with peaks at intervals of 4-5 days was reported in Gracilaria corticata (Mohan Joseph and Krishnamurthy, 1977), G. edulis (Rama Rao and Thomas, 1974) and G. verrucosa (Oza and Krishnamurthy, 1968). Similar trend in the discharge of carpospores was observed in the present study on Gracilaria corticata, G. edulis and Hypnea musciformis (Tables 5-8 & Fig. 3.).

Seasonal Changes in Spore Output:

Seasonality in the liberation of tetraspores was found in Gelidiella acerosa growing in the tide pools at Veraval (Sreenivasa Rao, 1971 a and 1974). In Gelidiella acerosa growing in the tide pools at Veraval, the liberation of tetraspores commenced by the end of April and the shedding of spores in maximum number of plants was over by the end of May. During October-November there was a second cycle of formation and subsequent liberation of tetraspores. The production of tetraspores during this

period of reproductive activity is less compared with that in April-May. Moreover the spore production season in October-November was shorter than that in April-May. The shedding period extended only for 25 to 30 days in each fruiting season (Sreenivasa Rao 1971 a and 1974). But in the present study on Gelidiella acerosa growing at Kilakarai shedding of tetraspores was observed throughout the year as reported for Gelidiella acerosa growing at Pudumadam (Umamaheswara Rao, 1974). In Gelidiella acerosa growing at Pudumadam shedding of tetraspores was observed during the entire fruiting period with peak spore output during May-June and November-December. The spore output was minimum during the two vegetative growth phases of this algae and though the number of stichidia per plant was more, the spore production was less in April and October. This may be due to the occurrence of immature tetrasporangia immediately after vegetative growth periods (Umamaheswara Rao, 1974). Spore shedding was found in all months of the year in Gelidium pusillum and Pterocladia heteroplatos growing at Visakhapatnam coast without any seasonal periodicity in the quantity of tetraspores and carpospores liberated (Kaliaperumal, 1979). In the earlier studies on Gelidiella acerosa, seasonal variation in the number of stichidia and peak discharge of tetraspores at particular periods of the year was reported

by Sreenivasa Rao, (1971 a and 1974); Umamaheswara Rao, (1974) and Rama Rao et. al.,(1976). In the present investigation, though spore shedding was seen in all months of the year, in Gelidiella acerosa seasonal veriations were not found (Fig. 38) and in this aspect it agrees with members of Gelidiales namely Gelidium pusillum and Pterocladia heteroplatos gorwing at Visakhapatnam coast (Kaliaperumal, 1979). Similarly there was no seasonality in the production of stichidia in Gelidiella acerosa (Fig. 3A).

Data on seasonal changes in the shedding of tetraspores and carpospores of Gracilaria corticata from Mandapam were collected by Umamaheswara Rao (1976). Shedding of tetraspores and carpospores was observed in all months of the year with marked variations in the spore output. The tetraspore output was maximum in March and April and another small peak in November-December with an increase in spore output from September. The carpospore production was maximum in March and again in September and October. The seasonal periodicity in carpospore output was somewhat different from that of tetraspores. The second peak in carpospore shedding was observed two months earlier and high values were also obtained in January and June. Mohan Joseph and Krishnamurthy (1977) observed seasonal changes

in the shedding of carpospores with maximum output on the first day and rhythmic liberation of carpospores was also found in this species collected from Mandapam. The tetraspore and carpospore output varied seasonally in Gracilaria corticata and Hypnea musciformis of Visakhapatnam coast, with peak shedding of spores in the periods between December and February/March and from August to October each year (Subba Rangaiah, 1978). Two peak periods of sporulation were observed in Gracilaria corticata occurring on the coast of Veraval. Laboratory experiments were conducted which showed the tetraspore shedding from April and August and carpospores shedding from November to December (Oza, 1979). Studies on the seasonal rhythm in the shedding of tetraspores and carpospores in Hypnea valentiae from Mandapam were carried out by Rama Rao (1979). Maximum number of tetraspores were released in February and carpospores in October. But similar trend was not observed in the liberation of tetraspores and carpospores in Gracilaria corticata growing at Pudumadam (Figs. 3C and 3D) in the present study.

Seasonal variations in the liberation of carpospores with peak activity at particular periods of the year was reported in Gracilaria edulis collected from Krusadai Island (Rama Rao and Thomas, 1974). But in Gracilaria

edulis collected from Thonithurai seasonal variations were not found in the release of tetraspores and carpospores (Figs. 4A and 4B). The duration of shedding of carpospores in Gracilaria edulis growing at Rameswaram increased from 3-4 days in February to 30 days in August and decreased from September to January. The daily periodicity was always maximum in the first day and decreased gradually but showed a second maximum after fourth or fifth day in the months of July-August where the number of days of shedding was prolonged. The total spore output per plant showed peak values in July and August which gradually decreased by January. Higher values of spore output were seen again in February-March while in April and May a total lack of spores was noticed (Rama Rao and Thomas, 1974). Seasonal variations in the liberation of spores with peak activity at particular periods of the year are reported in Gracilaria verrucosa (Jones 1959 a and Oza and Krishnamurthy, 1968) and Gelidiopsis variabilis (Kaliaperumal and Umamaheswara Rao, 1982). Rhythmic liberation of carpospores with peaks at intervals of 4-5 days were also recorded in Gracilaria verrucosa by Oza and Krishnamurthy (1968). Similarly as observed in the present investigation, there was no seasonal periodicity in the shedding of tetraspores and carpospores of Hypnea musciformis collected from

Pudumadam and Kilakarai (Figs. 4C and 4D) while it was observed in Hypnea musciformis from Visakhapatnam (Subba Rangaiah, 1979), and Hypnea valentiae from Mandapam (Rama Rao, 1979).

Diurnal periodicity in Spore Shedding :

Diurnal periodicity was observed in some members of Gelidales and other red algae with maximum shedding of spores at a particular time in a day. Diurnal periodicity in the liberation of spores with maximum output at a particular time in a day was not found in Iridophycus curnucopiae (Fukuhara, 1957). But periodicity in the liberation of spores was observed in members of Gelidiales and other red algae (Suto, 1950 a and b; Katada et al., 1953; Katada, 1955; Umamaheswara Rao, 1974 a; Kaliaperumal, 1979 and Ngan and Price, 1983) and Gigartinales (Matsui, 1969; Umamaheswara Rao, 1976; Subba Rangaiah, 1978; Kaliaperumal, 1979; Rama Rao, 1979 & Ngan and Price, 1983). Matsui (1969) observed the release of maximum number of tetraspores and carpospores from evening to mid-night in Gloiopeltis tenax and in the early morning hours in Gloiopeltis furcata. Umamaheswara Rao (1974 a) reported the periodicity in Gelidiella acerosa with peak spore output in the day time between 2 PM and 6 PM.

In Gelidiella acerosa growing at Kilakarai also diurnal periodicity with peak liberation of tetraspores in the afternoon from 2 P.M to 6 P.M. was found in the present study. It confirms with the observation made by Umamaheswara Rao (1974 a) on the diurnal periodicity in the output of tetraspores in Gelidiella acerosa growing at Pudumadam. Seasonal variations on the diurnal periodicity of spore output was observed in Gelidiales members such as Gelidium amansii (Katada et al., 1953) and Gelidium pusillum and Pterocladia heteroplatos (Kaliaperumal, 1979). But there was no change in the diurnal periodicity curves obtained for different months from October 1981 to September 1983 in Gelidiella acerosa (Figs. 5 and 6) and it is in confirmity with the results obtained for Gracilaria corticata, G. textorii, Gracilariopsis sjoestedtii and Hypnea musciformis growing along Visakhapatnam coast (Subba Rangaiah, 1978). Suto (1950 b) and Katada et al., (1953) found the shedding of spores in Gelidium amansii daily in the afternoon.

In Gracilaria corticata maximum spore output was observed during night time between 10 PM and 6 AM. (Umamaheswara Rao, 1976). Subba Rangaiah (1978) observed peak shedding of tetraspores and carpospores in Gracilaria corticata and Gracilariopsis sjoestedtii and tetraspores of Hypnea musciformis during night time between 2 AM and 6 AM.

In Gracilaria textorii maximum liberation of tetraspores as well as carpospores was seen in the afternoon between 2 PM and 6 PM. Data collected continuously for 2 days with tetrasporophytes and 3 days with cystocarpic plants indicated the occurrence of similar diurnal periodicity in the liberation of tetraspores and carpospores of the above algae.

Diurnal periodicity with a prominent peak in the liberation of spores was observed in Gelidium pusillum and Gelidiopsis variabilis and a definite peak in spore shedding was not seen in Pterocladia heteroplatos (Kaliaperumal, 1979). There was no difference in the time of peak shedding of carpospores and tetraspores in Gelidium pusillum and Pterocladia heteroplatos. In Gelidium pusillum peak output of spores was observed during night time between 6 PM and 10 PM or 10 PM and 2 AM. In Gelidiopsis variabilis peak shedding of tetraspores was found during the day time from 6 AM to 10 AM or from 10 AM to 2 PM. Rama Rao (1979) observed a definite diurnal periodicity in the shedding of carpospores in Hypnea valentiae. Ngan and Price (1983) recently collected data on the periodicity of carpospore and tetraspore discharge in 14 red algal taxa from the vicinity of Townswille region, Queensland, Australia under a variety of laboratory conditions at hourly or bi-hourly intervals over periods of 24 hrs or in some cases 48 hours.

In the diurnal periodicity of tetraspores discharge based on hourly records of spore output, the spore liberation was observed from 04.00 hrs to 10.00 hrs with peak at 06.00 hrs in Gracilaria edulis. The time of maximum output of tetraspores and carpospores in Gracilaria rhodotricha and Hypnea cervicornis and tetraspores in Gracilaria textorii, G. verrucosa, Hypnea pannosa and H. valentiae was found in the morning between 05.00 and 09.00 hours. The above observations is in confirmation with the data obtained in the present study for the three members of the order Gigartinales (Gracilaria corticata, G. edulis and Hypnea musciformis).

Differences in the time of peak shedding between tetraspores and carpospores was observed by some workers. Katada et al. (1953) found that the shedding time of carpospores in Gelidium amansii was always earlier (3-4 hours) and shorter than tetraspores. Subba Rangaiah (1978) observed maximum shedding of carpospores in Hypnea musciformis 4 hours earlier (10 PM to 2 AM) than peak tetraspore output. The data collected in the present study on Hypnea musciformis agrees with that of Subba Rangaiah's (1978) observations. But there was no difference in the time of peak tetraspore and carpospore shedding in Gloiopeltis tenax and Gloiopeltis furcata (Matsui, 1969), Gracilaria corticata (Umamaheswara Rao, 1976 and Subba Rangaiah, 1978), Gracilaria textorii

and Gracilariopsis sjoestedtii (Subba Rangaiah, 1978), Gelidium pusillum and Pterocladia heteroplatos (Kaliaperumal, 1979).

Seasonal variations in the diurnal periodicity of spore output were also investigated. Katada et al. (1953) showed that the time of peak shedding of tetraspores and carpospores in Gelidium amansii becomes gradually earlier (between 12.00 and 14.00 hours) in a day between June and September and it occurred later (after 14.00 hours) in a day during October and November. Similarly seasonal changes in the diurnal periodicity of tetraspore output in Gelidium pusillum and Gelidiopsis variabilis was observed by Kaliaperumal (1979). In Gelidium pusillum peak output of spores was observed between 6 PM and 10 PM from March to November and four hours later between 10 PM and 2 AM from December to February. In Gelidiopsis variabilis peak shedding of tetraspores was found between 6 AM and 10 AM from April to November and between 10 AM and 2 PM from December to March. But in Gracilaria corticata, G. textorii, Gracilariopsis sjoestedtii and Hypnea musciformis the diurnal periodicity of tetraspores and carpospores did not vary in different months or season of the year (Subba Rangaiah, 1978).

Though a definite peak at one period of the day as observed in the present study was not seen in the shedding of

tetraspores and carpospores in Gracilaria corticata, G. edulis and Hypnea musciformis, maximum liberation of spores occurred in these species between 10 PM and 2 PM (Figs. 7 to 17). This period coincides with the times at which maximum spore output was observed for Gracilaria corticata and Hypnea musciformis growing in India (Umamaheswara Rao, 1976 and Subba Rangaiah, 1978) and Gracilaria edulis and other species of Gracilaria and Hypnea such as Gracilaria rhodotricha, G. textorii, G. verrucosa, Hypnea cervicornis, H. pannosa and H. valentiae also growing in the vicinity of Townsville region, Queensland, Australia (Ngan and Price, 1983).

EFFECTS OF ENVIRONMENTAL FACTORS ON SPORE SHEDDING

For a successful cultivation of spores, we need to know the different factors affecting spore output. Effects of environmental factors like desiccation, salinity, light (intensity and photoperiod) and temperature on spore shedding have been reported by few workers. Sea water temperature and the above conditions are considered as important factors for controlling the growth and reproduction of intertidal algal population. Detailed studies on these ecophysiological aspects have not been made on the intertidal algae growing along the Indian shores particularly Mandapam coast. The scanty information available on spore output indicates that the response to various factors of the environment varies in different algae.

EXPOSURE TO AIR AND DESICCATION

Katada (1955) reported that desiccation in the shade has no inducing effect upon the shedding of tetraspores in Gelidium amansii and in these experiments the time of shedding was extended within about half a day. On the contrary, Matsui (1969), reported accelerating effect in Gloiopeltis species. Accelerating effect in liberation of spore was observed in Gloiopeltis tenax and Gloiopeltis furcata when the fronds were exposed to air.

In Gloiopeltis tenax fronds were exposed to air for 2 - 6 hours which hastened the liberation of spores and majority of spores were liberated within a short time, even 10 hours before the peak time of daily spore liberation. In Gloiopeltis furcata when exposed fronds were reimmersed around the time of peak daily liberation, a large quantity of spores were liberated immediately after reimmersion. Even if the liberation did not occur immediately after immersion, the exposure affected the time of subsequent liberation. In both species the number of spores liberated immediately after immersion gradually decreased if the exposure was prolonged beyond 6 hours.

In Gelidiella acerosa (Sreenivasa Rao, 1971 a) drying of tetrasporic plants in shade had no effect on spore output. The spore shedding decreased in the fronds exposed for 1-2 hours and prolonged drying of fronds for 4 to 12 hours injured the plants.

In Gracilaria corticata (Umamaheswara Rao, 1976), tetraspore output decreased markedly in thalli exposed for 1 hour and spore shedding was not seen in fronds exposed for a period of 2 to 6 hours. Carpospores were not at all liberated from cystocarps exposed even for 1 hour to air at room temperature. In the experiments conducted with tetrasporic thalli of Gracilaria corticata, Gracilaria textorii, Gracilariopsis sjoestedtii and Hypnea musciformis exposing upto 105 minutes to air in the room with 15 minutes intervals, the tetraspores output decreased in all plants with increase in the duration of exposure of fronds and maximum output was seen under continuously submerged conditions (Subba Rangaiah, 1978 and Umamaheswara Rao and Subba Rangaiah, 1980).

In the desiccation experiments conducted with tetrasporophytes of Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis growing at Visakhapatnam coast, maximum tetraspore output was obtained from the thalli kept under submerged conditions. The above observations agrees with the present study made in Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis.

According to to Umamaheswara Rao and Sanjeeva Reddy, (1982), maximum tetraspore shedding in Dictyota dichotoma was seen control experiments where the fronds were not exposed to air. The tetraspore output decreased even in fronds exposed to air for 15 minutes. With increase in the duration of exposure

to air, the spore output declined rapidly and total inhibition of spore shedding was found in fronds exposed for 120 minutes. But in the fronds of Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis exposed to air, spore output declined than in the fronds kept continuously under submerged condition (Figs. 18-21) indicating that exposure of fronds during low tides adversely affects spore liberation. Submerged condition was found favourable for maximum spore release in these four algae. These findings agree with the results obtained for Gelidium amansii (Katada, 1955), Gelidiella acerosa (Sreenivasa Rao, 1971 a), Gracilaria corticata (Umamaheswara Rao, 1976; Umamaheswara Rao and Subba Rangaiah, 1980; Subba Rangaiah, 1978), Hypnea musciformis, Gracilaria textorii and Gracilariopsis sjoestedtii (Subba Rangaiah, 1978; and Umamaheswara Rao and Subba Rangaiah, 1980), Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis (Umamaheswara Rao and Kaliaperumal, 1983) and Dictyota dichotoma (Umamaheswara Rao and Sanjeeva Reddy, 1982). The maximum tetraspore shedding in Dictyota dichotoma was seen in control experiments where the fronds were not exposed to air. The tetraspore output decreased even in the fronds exposed to air for 15 minutes. With increase in the desiccation of exposure to air the spore shedding was found in fronds exposed to 120 minutes.

SALINITY

Any significant variation was not observed in the shedding of spores between 17‰and 52‰salinity in Gloiopeltis tenax and Gloiopeltis furcata by Matsui, (1969). More number of spores were liberated in 15.6 chlorinity (28.19 ‰ salinity) and the spore output decreased at 11.0 (19.89 ‰ salinity) and 8.2 chlorinity (14.83 ‰ salinity). At 5.4 chlorinity (9.78 ‰ salinity) the number of spores liberated were very low. Matsui (1969) found that the tetraspore liberation was not significantly altered in salinities between 17 ‰ and 42 ‰ in Gloiopeltis tenax and Gloiopeltis furcata. At salinities below 12 ‰ and above 60 ‰ liberation of spores was delayed and the number of spores also decreased in these two plants. Monospore release was found in Acrochaetium endophytium by White and Boney (1969) in the media of 19.2 ‰ - 49 ‰ salinity, while plants died in 6.4, 12.8 ‰ S and in salinities above 49 ‰. Normal production of zoospores or gametes was found in Ulva fasciata by Mohsen et al., (1972) in the salinity range between 20 ‰ and 35 ‰. Higher salinities from 35 to 45 ‰ enhanced both the formation of swarmers and their discharge. On the other hand salinities below 20 ‰ retarded both the maturation and discharge of swarmers and below 15 ‰ no dehiscence took place.

The spore output varied in experiments conducted by Subba Rangaiah et al., (1975), Subba Rangaiah (1978) and Umamaheswara Rao and Subba Rangaiah (1980) in different salinities ranging from 10-60 %o and the optimum range observed for peak shedding of spores was 30-40 %o S. in Gracilaria corticata, Gracilaria textorii and Gracilariopsis sjoestedtii and 20-30 %o in Hypnea musciformis. Umamaheswara Rao and Kaliaperumal (1983) conducted spore output experiments with tetrasporic thalli of Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis in different salinities ranging from 0 to 70 %o. In Gelidium pusillum and Pterocladia heteroplatos, spore shedding was found from 10 to 60 %o with peak discharge at 30 %o salinity.

In Gelidiopsis variabilis spore shedding was seen only in three salinities (20, 30 and 40 %o) with lowest value at 20 %o S. Salinities < 20 %o completely inhibited spore shedding and at 40 %o salinity the spore output was more than in Gelidium pusillum and Pterocladia heteroplatos. Of the eight different salinities (0-70 %o salinity) tested with Dictyota dichotoma by Umamaheswara Rao and Sanjeeva Reddy (1982), spore output was observed in salinities ranging from 10 %o to 60 %o; From 10 %o salinity onwards the spore output increased and maximum shedding of tetraspores was observed at 30 %o salinity. The spore output declined from 40 %o salinity and it was minimum at 60 %o salinity. But as observed in the present

study salinity of sea water influenced sporulation in Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis and spore release decreased markedly below 20 %o and above 40 %o salinities. The optimum salinity range observed for maximum shedding of spores in the four algae was 30-40 %o (Figs. 22-25). Though the optimum range of salinity varied on monospore production from conchocelis phase in Porphyra (Yamasaki et al., 1957), monospore release in Acrochaetium endophytium (White and Boney, 1969), formation and discharge of swarmers in Ulva fasciata (Mohan et al., 1972), tetraspores output in Gracilaria corticata, G. textorii, Gracilariopsis sjoestedtii, and Hypnea musciformis (Subba Rangaiah et al., 1975; Subba Rangaiah, 1978 and Umamaheswara Rao and Subba Rangaiah, 1980). In Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis (Umamaheswara Rao and Kaliaperumal, 1983), and Dictyota dichotoma (Umamaheswara Rao and Sanjeeva Reddy, 1982), the general trend observed in the formation and release of reproductive elements in different salinities in these algae was similar to that observed in the present study on Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis. The optimum range of salinity found in the laboratory experiments is nearer to the annual range of 28.28 - 36.25 salinity recorded during the present (Figs. 55-57) and earlier investigations (Prasad, 1954 and Jayaraman, 1954) for the inshore waters of Mandapam area. These findings indicate that the salinity of the

sea water in the nearshore area of Mandapam is suitable for liberation of maximum number of spores in all months of the year.

LIGHT INTENSITY

In some species of the order Gelidiales spore output studies were carried out by Katada (1955). He observed that the shedding time in the case of tetraspores was earlier in the light than in the dark, but carpospores were not affected. Rao (1971 a) also reported similar observations in Gelidiella acerosa, where spore liberation was slightly promoted by light. Monospores were obtained in the light intensities of 19-500 lumens/sq.ft. (205-5382 lux). The spores bleached and died soon after release between 480-500 lumens/sq.ft. (5167-5382 lux) and spore output was not found in dark. Massive spore output over long periods was seen in the light intensity range of 50-110 lumens/sq.ft. (538-1184 lux). In Monostroma (Ohno, 1982) liberation of gamete was found between 500 and 5000 lux and at higher intensities of 10,000 and 20,000 lux no liberation of reproductive bodies occurred, although gamete formation was observed. However, gamete liberation was seen at 10,000 and 30,000 lux light intensities in Monostroma nitidum (Ohno and Nozawa, 1972).

Subba Rangaiah (1978) and Umamaheswara Rao and Subba Rangaiah (1980) reported maximum shedding of tetraspores in Gracilaria corticata, Gracilaria textorii and Gracilariopsis sjoestedtii

in complete darkness. The values obtained at 750 ± 50 lux were slightly less than those obtained in darkness and the spore output decreased gradually at 1500 and 2000 lux light intensities. But in Hypnea musciformis spore output was higher at 750 ± 50 lux light intensity than in darkness and the spore production declined in the other two light intensities. Umamaheswara Rao and Kaliaperumal (1983) found that peak discharge of tetraspores in Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis at 500 lux. From 1000 lux the spore output decreased with increasing illuminance in Gelidium pusillum and Gelidiopsis variabilis and complete inhibition was seen in these two algae at 5500 lux. In Pterocladia heteroplatos the peak output was at 500 lux. Changes observed between 1000 to 3000 lux were not marked and lowest values were obtained at 4500 and 5500 lux, light intensities.

In the experiments carried out with the fruiting thalli of Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis at different light intensities, in the present study spore release occurred from 0 to 4000 lux. This observation agrees with those of Ohno (1972) on gamete liberation in Monostroma, White and Boney (1969) on monospore output in Acrochaetium endophytium and Umamaheswara Rao and Kaliaperumal (1983) on tetraspore shedding in Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis

variabilis. Subba Rangaiah (1978) and Umamaheswara Rao and Subba Rangaiah (1980) observed peak discharge of spores in complete darkness in Gracilaria corticata, G. textorii and Gracilariopsis sjoestedtii whereas in the present study maximum liberation of spores was observed at 500 lux in Gelidiella acerosa, Gracilaria corticata and G. edulis (Figs. 26-28). The results obtained on these three algae in the present study confirms with the results of Umamaheswara Rao and Kaliaperumal (1983) for Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilibis in which maximum tetraspore output was observed at 500 lux.

Peak output of spores was found at 1000 lux in Hypnea musciformis growing on Mandapam coast (Fig.29) and it is similar to that observed for Hypnea musciformis growing on Visakhapatnam coast (Subba Rangaiah, 1978 and Umamaheswara Rao and Subba Rangaiah, 1980) where maximum spore output was seen at 750 ± 50 lux. In Monostroma nitidum gamete liberation was seen at very high light intensities ranging from 10,000 to 30,000 lux (Ohno and Nozawa, 1972). But in Monostroma inhibition of spore emission was found at 10,000 and 20,000 lux (Ohno, 1972) and in Gelidium pusillum and Gelidiopsis variabilis at 5,500 lux (Umamaheswara Rao and Kaliaperumal, 1983). In Pterocladia heteroplatos lowest values in spore release were obtained at high light intensities of 4,500 and 5,500 lux (Umamaheswara Rao and

Kaliaperumal, 1983). Similarly in the present investigation also minimum number of spores released was seen in the four algae at 4,000 lux light intensity.

Temperature:

The relation between sporulation of seaweeds and sea water temperature was studied by Suto (1950 a and b). According to Suto (1950 a) spore shedding in seaweeds takes place when the sea-water temperature has reached a level optimum for each species. The spore liberation in Gelidium amansii takes place daily in the afternoon, probably because the right temperature is reached then. He further stated that shedding season started in Gelidium when the sea water temperature rose to 20° C for carpospores. There was an optimum temperature range for shedding of spores and abnormal temperature delayed or hastened shedding by about 20 days. The direct evidence of temperature influence on spore shedding was later supported by Katada (1955) also working on Gelidiales for Gelidium amansii, who observed that the higher the temperature of the preceding night, the earlier the shedding of spores the following day. The shedding time of tetraspores and carpospores was not restricted to the afternoon of a given day but varied depending upon the temperature of the sea water in the field. It was also found that there was no change in the

shedding time in the next day when the water temperature was less than 25° C. In the experiments conducted by Fukuhara (1957) with Iridophycus cornucopiae, the diurnal periodicity in the shedding of spores was not affected by water temperature. Shedding of tetraspores and carpospores in Gelidium was observed when the sea water temperature rose to 20° C and 24° C respectively (Suto, 1950 b). The optimum range observed for spore liberation in different species of Porphyra varied from 10-25° C (Kurogi and Akiyama, 1966) and from 1-15° C (Kurogi et al., 1967).

Kurogi and Akiyama (1966) examined the effect of water temperature on the liberation of monospores on 6 species of Porphyra, namely P. tenera, P. kuniedai, P. yezoensis, P. angusta, P. suborbiculata and P. pseudolinearis. Monospores were liberated between 10° and 25° C in P. tenera, P. yezoensis and P. angusta. The liberation was little or not seen in P. kuniedai, P. suborbiculata and P. pseudolinearis at these temperature ranges. Kurogi et al. (1967) noticed differences in the optimum temperature of monospore liberation between the conchocelis of the autumn and spring plants of Porphyra umbilicalis, although experiments with these plants were carried out at the same time. Abundant monospores were liberated at 5°, 10° and 15° C in monoecious spring plants. There was no significant influence on spore liberation in the temperature range of

15-25° C in Gloiopeltis tenax and 10° C-20° C in Gloiopeltis furcata. At temperatures above or below these ranges liberation was delayed and the number of spores shed also decreased (Matsui, 1969).

Tetraspore shedding varied at 5 different temperatures ranging from 15° C to 35° C in Gracilaria corticata, Gracilaria textorii and Hypnea musciformis (Subba Rangaiah, 1978 and Umamaheswara Rao and Subba Rangaiah, 1980). There was no spore discharge at temperatures below 15° C and above 35° C and peak shedding was seen at 30° C. The temperature between 25° C and 30° C was considered as optimum for discharge of maximum number of spores in these three algae. The tetraspore output varied at 9 different temperatures ranging from 0° C to 45° C tested with the tetrasporic thalli of Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis (Umamaheswara Rao and Kaliaperumal, 1983). In Gelidium pusillum spore output increased from 15° C with peak shedding at 25° C. At 30° C and 35° C the spore cutput declined rapidly. In Pterocladia heteroplatos minimum shedding was obtained at 10 and 15° C and also at 40° C showing its ability to liberate reproductive elements at low and high water temperatures. Between 20 and 35° C the changes observed in P. heteroplatos were similar to those of Gelidium pusillum with peak discharge of spores at 25° C. In contrast, in Gelidiopsis variabilis spore output was

seen only at three temperatures (25, 30 and 35° C) with a maximum at 30° C. There was a sudden fall in the quantity of spores liberated by this algae at 35° C. Peak discharge of spores was found at 25° C in *Gelidium pusillum* and *G. heteroplatos* and at 30° C in *G. variabilis* showing that the temperatures between 25° C and 30° C was optimum for maximum liberation of spores in these three species. In the experiments conducted with *Dictyota dichotoma* at different temperatures ranging from 10 to 45° C, maximum output of tetraspores was seen at 30° C. There was no shedding of spores from the fronds subjected to 10° C, 40° C and 45° C temperatures. When compared to the other temperatures tested, the values obtained at 25° C was slightly high indicating that temperatures from 25 to 30° C were favourable for maximum liberation of tetraspores in *Dictyota dichotoma* (Umamaheswara Rao and Sanjeeva Reddy, 1982).

In *Gloiopeltis* spp. peak output of spores was reported from 10° C - 25° C (Matsui, 1969). The optimum range of temperature for the species of *Gelidium*, *Porphyra* and *Gloiopeltis* was found to be low as compared with those for the maximum release of spores in *Gelidiella acerosa*, *Gracilaria corticata*, *G. edulis* and *Hypnea musciformis* growing in the vicinity of Mandapam. The optimum temperature range for maximum liberation of spores in these four species was 25° C - 30° C (Figs. 30-33) as reported for the release

of tetraspores in Gelidium pusillum, Pterocladia heteroplatos, Gelidiopsis variabilis, Gracilaria corticata, G. textorii, Hypnea musciformis and Dictyota dichotoma growing at Visakhapatnam coast (Subba Rangaiah, 1978; Umamaheswara Rao and Subba Rangaiah, 1980; Umamaheswara Rao and Sanjeeva Reddy, 1982 and Umamaheswara Rao and Kaliaperumal, 1983). This temperature range coincided with the annual range of surface sea water temperature recorded for the inshore waters of Mandapam during the present investigation (Figs. 55-57) as well as in the earlier observations (Prasad, 1954; Jayaraman, 1954 and Umamaheswara Rao, 1972 b).

Photoperiod:

The effect of day length on sporogenesis has recently been reviewed by Dixon and Richardson (1970). In Bangia fusco-purpurea, the Chonchocelis phase produces monosporangia only in short day photoperiod (9L : $\overline{15}$ D, 12L : $\overline{12}$ D, or 9 L : $\overline{9}$ D). Literature available also suggests that day length or photoperiod influence the spore production. In Porphyra tenera (Iwasaki, 1961) monospore formation and release of fertile monospores were induced by short day condition of 8-11 hours light period. Work on photoperiod induction and liberation of monospores from the conchocelis phase of 5 species of Porphyra were carried out by Kurogi and Suto (1962). The adequate dark period for the liberation of monospores in Porphyra tenera, P. kuniedai, P. yezoensis,

P. pseudolinearis and P. angusta was 12-16 hours (Short day condition) while Kurogi and Suto (1967) observed more liberation of monospores in Porphyra umbilicalis under long day conditions. The Acrochaetium endophyticum (White and Boney, 1969) plants kept under long day conditions (18 $\pm \overline{6}$ LD cycle) produced large number of monospores at all light intensities ranging from 30-500 lumens/sq.ft. (323-5382 lux). In Monostroma, Ohno (1972) found long day treatment (18-24 hours light period at 3000 lux) resulted in faster gamete liberation than fronds given short day treatment at the same light intensity or fronds maintained under natural day-night regime. In Gelidiella acerosa (Umamaheswara Rao, 1974 a) spore output was found at 0 + $\overline{24}$, 8 + $\overline{16}$, 16 + $\overline{8}$ and 24 + $\overline{0}$ light and dark periods and maximum shedding was observed at 16 + $\overline{8}$ LD cycle. The present observations made on Gelidiella acerosa agree with the findings of Umamaheswara Rao (1974 a).

In Gracilaria corticata release of tetraspores and carpospores was observed in different light and dark periods (Umamaheswara Rao, 1976). The tetraspore output was maximum in 0 + $\overline{24}$ LD cycle and with increase in the light period the spore shedding gradually deceased. The carpospore output varied under different light and dark cycles and maximum number of spores was liberated in 4 + $\overline{20}$ LD cycle. Similarly maximum shedding of tetraspores was also observed by Subba

Rangaiah (1978) and Umamaheswara Rao and Subba Rangaiah (1980) in Gracilaria corticata, Gracilaria textorii, Gracilariopsis sjoestedtii and Hypnea musciformis at 0 + $\overline{24}$ LD cycle, and the spore output declined with increase in the duration of photoperiod. The values obtained at 4 + $\overline{20}$ LD cycle were also higher than in other photoperiods. The above findings is in confirmation with the present investigations made on three species of the order Gigartinales (Gracilaria corticata, G. edulis and Hypnea musciformis).

Recent studies made on the combined effects of light intensity and photoperiod have indicated that the amount of energy received by the plants affects their growth and reproduction and while reviewing the earlier work, Dixon and Richardson (1970) described the interacting effect as photosynthetic effect. Murray and Dixon (1973) reported the effect of light intensity and photoperiod on apical cell division in Pleonosporium squarrulosum. Rate of cell division was found to be affected by both light intensity and light periods of 16 + $\overline{8}$ LD and 8 + $\overline{16}$ LD and increase in cell division was found upto a value of 538 mean daily Illuminance (Illumination in lux multiplied with photoperiod in hours per day). The combined effects of illuminance and duration of light on the shedding of tetraspores from Gelidium pusillum, Pterocladia heteroplatos and Gelidiopsis variabilis was recently studied by Umamaheswara Rao and Kaliaperumal (1983). At 500 lux spore

output increased gradually and peak shedding was observed under long day conditions between 16:$\overline{8}$ and 24 : $\overline{0}$ LD photoregimes. At higher illuminance maximum shedding was seen under short day conditions. Maximum shedding of spores at 2000 and 3000 lux in Gelidium pusillum and Pterocladia heteroplatos was observed at 8 : $\overline{16}$ LD cycle. At 4500 lux spore output was high in these two species under 4:$\overline{20}$ LD cycle. (Although variation exists in relation to intensity and duration of light, spore output was low at higher illuminance values as observed in the data collected under continuous light. The variations in the mean values of spore shedding were observed in darkness (0:$\overline{24}$ LD) and are due to the use of materials collected at different times of the year). Thus the role of light (intensity and photoperiod) in inducing spore shedding is still obscure and that further work needs to be done to investigate this relationship in other seaweeds of economic importance.

In the combined effect of light intensity and day length (light and dark cycles) the earlier works in Porphyra spp. that indicate the release of reproductive bodies were induced by short day conditions only are by Iwasaki, (1961) and Kurogi and Suto, (1962) in Gracilaria corticata by Umamaheswara Rao, (1976) and Subba Rangaiah, (1978) in Gracilaria textorii, Gracilariopsis sjoestedtii and

Hypnea musciformis by Subba Rangaiah, (1978) and in long day conditions in Porphyra umbilicalis by Kurogi and Suto, (1967), in Acrochaetium endophytium by White and Boney, (1969), in Monostroma by Ohno, (1972) and in Gelidiella acerosa by Umamaheswara Rao, (1974). In Bangia fusco-purpurea, the Chonchocelis phase produce monosporangia (Dixon and Richardson, 1970) only in short day photo-regimes (9L : 15D, 12L : 12D, or 9L : 9D). Similarly the Chonchocelis phase of Porphyra tenera produced mono-sporangia (Kurogi and Suto, 1962) only in a short day photoregimes. The same was also observed in Pikea cali-fornia which produces monospore under 8L : 16D photoregimes (Scott and Dixon, 1971).

From the above it is seen that in the first two genera (B.fuscopurpurea & P. tenera) the response has been shown to be truly photoperiodic since sporogenesis is inhibited by light interruption in the middle of the dark period. In Acrochaetium pectinatum tetrasporogensis occurs only in photoperiods of 10 hours or less (in a 24 hour cycle) but exposure to light in the middle of the dark period (West 1968) was not inhibitory, hence in this case the response does not appear to be truly photoperiodic. On the other hand Pseudogloiphloea confusa showed (Ramus, 1969) a complex interaction of temperature-light intensity and light duration in tetrasporogenesis. In photoperiods

of 16L : 8D, the maximum spore production was at a temperature of 20° C and at light intensity of 2,700 meter candles but when the temperature was reduced to 15° C and the photoperiod and light intensity remained the same, spore production was reduced. When the thalli were grown at 15° C under a photoperiod of 16L : 8D and at 1,100 meter candles light intensity, spore production was totally inhibited. Thus day length is reported to be an important factor in the production of spores of some marine algae. In his studies on Porphyra tenera, Kurogi (1959) observed that daily photoperiods of 8-11 hours not only induced monospore production and maturation but also induced the release of the monospores. In Gelidium pusillum peak spore output was observed at 16L : 8D in 500 lux and at 8L : 15D in 2000 lux light intensity. At 4500 lux light intensity high spore shedding was seen in complete darkness (0L : 24D) than in 4L : 20D. Similar trend in spore shedding was observed at 500 and 4500 lux light level in Pterocladia heteroplatos and at 500, 2000 and 3000 lux in Gelidiopsis variabilis (Kaliaperumal, 1978).

In the present study, peak liberation of spores was noted under long day conditions at low light intensity and at high light intensity under short day as well as under long day lengths. In Gelidiella acerosa maximum tetraspores were obtained at 500 lux light intensity under a photoperiod of 24L : 0D, at a laboratory room temperature of 30° C. At 2000 lux light intensity maximum spore output was obtained

at 16L : 8D, 20L : 4D photoperiods and at high light intensity (4000 lux) maximum spore shedding was seen in short day length of 4L : 20D as well as in complete darkness. Similar results were obtained for tetrasporogenesis and carposporogenesis in Gracilaria corticata, G. edulis and Hypnea musciformis. Thus day length appears to be an important factor in the spore production and spore shedding. Their interacting effects show that the amount of light energy received by plants influences spore release and this periodicity in the discharge of spores is due to the photosynthetic effect as has been described by Dixon and Richardson (1970). Similar photosynthetic effect was observed by Murray and Dixon (1973) in the division of apical cells in Pleonosporium squarrulosum. From the present study on spore shedding it may be presumed that the Mean Daily Illumination is an important factor in marine algal growth and reproduction.

GERMINATION OF SPORES

Information available in the literature indicates that the rate of germination of red algal spores varies in different months of the year e.g. in Gelidium robustum though fruiting plants were found throughout the year, spores germinated in the spring and early summer (Barilotti and Silverthorne, 1972). Another similar observation was reported by Prince and Kingsbury (1973) for seasonal variations in the growth of germlings of Chondrus crispus. Data obtained in the present

study on Gelidiella acerosa do not agree with the above findings as the germination of spores were observed throughout the year. There was no particular season for spore germination as the fruiting plants were present throughout the year of study and spores liberated settled at the bottom of the petri dishes and germinated soon after settlement. This was observed during the spring tide periods throughout the year of study. Germination of tetraspores and carpospores of Gracilaria corticata, G. edulis and Hypnea musciformis was also observed throughout the year of study, except in the carposporic plants of Hypnea musciformis which were available only in some months at stations II and III.

In the other gelidiaceous algae e.g. Gelidium pusillum and Pterocladia heteroplatos highest number of dividing spores were observed during and after the peak growth period (Kaliaperumal, 1979), whereas in Gelidiopsis variabilis spores did not germinate within 24 hours. In the present study the spores of Gelidiella acerosa germinated soon after liberation and settlement at the bottom of the petri dish. The germination rate was higher in Gelidiella than that observed in species of the order Gigartinales e.g. Gracilaria corticata, G. edulis and Hypnea musciformis collected from the vicinity at Mandapam region. The tetraspores and carpospores also germinated within 24 hours of liberation in the above three species of the order Gigartinales.

There was no seasonality in germination of spores as the reproductive plants of tetraspores and carpospores were found throughout the year and plants were collected during the spring tide periods. The spores (tetraspores and carpospores) germinated a few hours after liberation from the parent thallus. These observations suggest that during the two spring tide periods in each month maximum spore output and germination takes place than at other times.

Seasonal germination of spores was observed by some workers. Barilotti and Silverthorne (1972) reported seasonal germination of spore in Gelidium robustum from Baja California, in which juvenile thalli were observed on artificial substrata only in February. Though fruiting plants were seen throughout the year, the spores released during the spring and early summer were successful in producing young thalli on new substrata. In Chondrus crispus Prince and Kingsbury (1973) observed low sporulation and growth rates in winter and spring months and maximum sporulation and growth rates in early fall. Subba Rangaiah (1978) observed monthly variations in the number of dividing tetraspores and carpospores in Gracilaria corticata and Hypnea musciformis released on the first day (within 24 hours) from December 1974 to April 1976. The germination rate varied from a minimum of 11 % to a maximum of 60 % in the two red algae and highest number of dividing spores were seen during the peak periods of

spore shedding from December to February and from June to August.

Some preliminary data were collected on the percentage frequency of germination of tetraspores and carpospores of Gelidium pusillum and tetraspores of Pterocladia heteroplatos by Kaliaperumal, (1979). He found that the germination rate of tetraspores in Gelidium pusillum varied seasonally from a minimum of 0.3 % to a maximum of 13.6 % and that of carpospores from 0.2 to 39.1 %. Highest rate of germination (within 24 hours period) was observed in tetraspores and carpospores of Gelidium pusillum in February and in general high germination rate was observed during and after the peak growth season. In Pterocladia heteroplatos the germination rate of tetraspores was less than that observed in Gelidium pusillum and data obtained in different months ranged from 0.5 to 4.1 %. The germination rate was less than 1 % except in the month of September. Only 4.7 % of carpospores of Pterocladia heteroplatos germinated in experiments conducted during September. In other months there were no divisions in the carpospores liberated. Dividing spores were not observed (within 24 hours) in Gelidiopsis variabilis during the two and a half years' seasonal study on spore output (Kaliaperumal, 1979). During the present investigation on germination of spores (tetraspores and carpospores of the four selected species of red

algae), it is observed that the liberated spores do not follow any regular seasonal periodicity in the germination as reported by N. Kaliaperumal (1979) Subba Rangaiah(1978)

Spore germination and growth have been shown to be influenced by environmental factors such as desiccation, salinity, light and temperature. In experiments conducted at room temperature with Gelidium pusillum, maximum germination rate (18.5 %) was seen in controls and the germination rate decreased with increase in the duration of exposure upto 45 minutes (Kaliaperumal, 1979). Germinating spores were found in Pterocladia heteroplatos between 15 and 60 minutes exposure periods and in fronds exposed for more than one hour spore germination was not seen (Kaliaperumal, 1979). In the present study of the spores easily germinated in the fronds(fertile) kept under submerged conditions, than those fronds which were exposed to air.

In Gracilaria corticata dividing spores were found in salinities ranging from 20 to 40 %o with their maximum number at 30 %o and in Hypnea musciformis though peak output was found at 20 %o the rate of spore germination was maximum at 30 %o (Subba Rangaiah, 1978). In different salinities tested with the tetraspores of Gelidium pusillum and Pterocladia heteroplatos germination of spores

was found only in Gelidium pusillum at 20 and 30 ‰ and the values were 1.0 and 0.7 ‰ respectively.

The effect of light intensity on the germination of carpospore in Gracilaria verrucosa was studied by Jones (1959 a). Development of carpospores was not observed by him when the carpospores were exposed to high light intensities for 4 to 5 hours daily. Spore germination was also observed in Acrochaetium endophyticum by White and Boney, (1969) under 19-420 lumens/sq.ft. (205-4521 lux) and it was not found at dark and 480-500 lumens/sq.ft. (5167-5382 lux). In Gracilaria corticata and Hypnea musciformis though peak production of spores was observed in dark and low light intensity, germination rate increased from 0 to 1500 lux intensity and thereafter slight decrease was seen by Subba Rangaiah, (1978). The rate of germinating spores was high between 1500 and 3000 lux light intensities in Gelidium pusillum and the values obtained at 500 and 1000 lux light intensities were less than those obtained in dark. In light intensities above 3000 lux there were no dividing spores. Similar trend was not observed in Pterocladia heteroplatos by Kaliaperumal, (1979).

Katada (1949 and 1955) studied the effect of temperature on the germination of carpospores and tetraspores in Gelidium amansii. The optimum range of temperature under experimental conditions was found to be about 24 °C - 26 °C. Below this range of temperature the germlings developed slowly but were healthy in general, while above 28 °C the sporelings died quickly. In Iridophycus cornucopiae the upper and lower limits of temperature for the germination of carpospores as well as tetraspores were about 3 ° - 23°C and the optimum temperature was 7° - 15°C (Fukuhara, 1968). The effects of temperature and salinity on the growth of sporelings of Gelidium amansii were studied by Ohno(1969). He reported that the growth decreased above and below normal sea water concentration and reduction in growth was more at 25 °C than at 10 °C. Spore germination was not seen at low temperatures of 10 °C and 15 °C in Gracilaria corticata and Hypnea musciformis. Dividing spores were found between 20 °C and 30 °C and rate of germination was maximum at 30 °C. These temperatures agree with the surface sea-water temperatures recorded along the Visakhapatnam coast (Subba Rangaiah, 1978). In experiments conducted at different temperatures though the values were irregular, germination rate increased from low to high temperatures both in Gelidium pusillum and Pterocladia heteroplatos

and high values were obtained at 30 °C and 35 °C by Kaliaperumal, (1979).

In relation to the influence of environmental parameters on the germination and further growth of germlings, in Gelidium amansii was observed by Ohno, (1969). He showed that the growth of sporeling decreased above and below the normal salinity of sea water. In Gracilaria verrucosa, Jones, (1959) did not observe development of carpospores when exposed to high light intensity for 4 to 5 hours daily. White and Boney (1969) also did not observe germination of spore in Acrochaetium endophyticum in dark as well as in high light intensities of 480-500 lumens/sq.ft. (5167-5382 lux). Similarly Katada, (1949 and 1955) reported an optimum range of 24 °C - 26 °C for the development of carpospores and tetraspores in Gelidium amansii. From the present investigations on spore germination given in Figs. 45 to 54, it may be pointed out that submerged condition of the fronds, sea water salinity around 20 to 35 ppt., light intensity of 500 lux to 3000 lux and temperature of 25 °C to 35 °C are favourable for germination of spores in Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis. Complete darkness, short day conditions as well as long day conditions were also suitable for spore germination as observed in the present studies.

These are in confirmity with the findings of Katada (1949 and 1955); Jones, (1959); Ohno (1969); White and Boney (1969); Burns and Mathieson, (1972). In Gigartina stellata the optimum germination of spores occurred at 30 %oS and maximum growth rate at 25, 30 and 35 @o salinity. The spores did not germinate at 15 %o, but showed some germination and growth at 50 %o as is found in the present observations made on the germination of selected red algae, is given in (Figs. 47-48), which also agree with the observations made by Subba Rangaiah (1978) on some species of G$gartinales, and by Kaliaperumal, (1979) on two species of Gelidiales.

Mode of spore germination :

The divisions in the germination of spores were observed in the tetraspores and carpospores of the three members of the order Gigartinales studied. Gracilaria and Hypnea showed a similar pattern of segmentation of spore. In the order Gelidiales (Gelidiella acerosa) where a lateral protuberance is seen where the protoplāsm from the original spore migrates into the protuberance and further divisions were observed in the lateral protuberance from which adult thallus developed. Thus type of spore germination found in Gelidiella acerosa is characteristic of the order Gelidiales. It is described as 'Gelidium type' of germination(Fritch 1945)

In Gracilaria corticata, G. edulis and Hypnea musciformis (Gigartinales) the protoplasm remains enclosed in the original spore and divides by a wall perpendicular to the substratum, giving rise to two cells, and then by the formation of a wall perpendicular to the first one gives rise to four cells, forming a quadrant. The four celled sporeling later by further division forms a multicellular structure. This later on forms a disc-like body from which rhizoids, unicellular hairs and young thalli are formed This type of division observed in Gigartinales is described as 'Dumontia type' by Chemin (1937), Fritsch (1945). Fragmentary studies on germination of red algal spores have been shown to be of diagnostic value in determining the taxonomic and phylogenetic relationships (Katada 1955; Chihara & Kamura, 1963). Similar types of observations were reported in the order Gigartinales (Rhodophyta) by Subba Rangaiah (1976) in the germination of tetraspores and carpospores of Gracilaria corticata and Hypnea musciformis occurring in the Visakhapatnam coast. Studies by Jones (1959) on Gracilaria verrucosa, Feldmann (1967) on Corydelcladia erecta, Burns & Mathieson (1972) on Chondrus crispus have confirmed the 'Dumontia' or "mediate discalis" type of spore germination in the above algae.

Hydrography :

The environmental parameters (e.g. sea water temperature, salinity, dissolved oxygen and pH) vary seasonally and this (Concover 1964) cause some species to disappear and reappear according to the season and optimum conditions.

Temperature :

Temperature is one of the most important factors affecting the growth, reproduction and many other activities in the living organism. The mean temperature of a given locality the seasonal and the annual variations do play very important roles in the littoral, or intertidal to sub-tidal zones, varying in seasonal and geographical distribution pattern of many marine algae. The effect of temperature on the validity and growth of seaweeds and developing sporelings has been investigated by several workers. In Scinaia furcellata and Helminthocladia purpurea the critical upper temperature limit is 35 °C to 40 °C. (Chemin 1937). He further reported that the tetraspores of Gelidium latifolium tolerated a temperature maintained at 39 °C for 30 minutes; but the carpospores of Callophyllis laciniata succumbed at 36 °C after 30 minutes. In Gelidium amansii the favourable range of temperature for the development of carpospores is 24 °C to 26 °C and below

24 °C development of sporeling is very slow, whereas above 28 °C the sporelings die quickly. In Codium fragile the favourable temperature for spore germination (80%) (Weber 1968) is 22 °C, whereas as at 8 °C there is only 10% spore germination. Sporeling from the monospores of Porphyra require a temperature ranging from 6° to 14°C for maximum germination, (Yendo, 1919) while those of tetraspores and carpospores of Chondrus crispus showed optimum growth at 15°C and at 20°C there was no germination (Chen and Mclachlan 1972). In Gigartina stellata, the growth rate of the sporeling was accelerated with increase in temperatures to 19 °C (Burns and Mathieson 1972). At relatively high temperatures the increased respiratory rates may exhaust the algal food reserves. If this is prolonged the growth of algae would be arrested (Moore 1958). In tropical intertidal zones, one would expect that during the period of low tide emersion, direct insolation causes algal habitats to be subjected to relatively high temperatures. Only algae with a high tolerance to elevated temperatures can live higher up on the shore, hence temperature is one of the causal factors of vertical zonation in the distribution of sea weeds.

Figs. 55-57 give the seasonal variations in the monthly observations of temperature, salinity, dissolved oxygen and pH of the sea-water in the three collection areas in the vicinity of Mandapam. These findings suggest that sea water temperature ranging from 25.8°C to 31.9°C, salinity from 28.28 to 36.25‰, dissolved oxygen of 2.67 to 6.33 ml/l and pH of 8.0 to 8.7 occurring in natural environment are favourable conditions for growth, reproduction, sporulation, spore germination and further development of sporelings to adult thallus of the seaweeds

Generally the ranges of environmental tolerance of marine algae are related to the habitats of the algae in which they grow. The above findings are in agreement with the similar observations made by Ohno (1969) who found that the growth rates of the early stages of Ulva pertusa and Porphyra tenera were maximum at salinities in the neighbourhood of normal sea water. In Chondrus crispus the percentage of carpospore germination and the growth rate of the sporeling varied (Burns & Mathieson 1972) according to the combined effects of temperature and salinity.

Salinity of the medium in which the marine algae and algal sporelings grow is one of the parameters which is considered to influence many metabolic processes in marine organisms. A given algal species in question grows best in the medium whose salinity is more or less similar to that in their natural habitats.

Ohno (1969) in his observations found that the growth rates of the early stages of Ulva pertusa and Porphyra tenera were maximum at salinities in the neighbourhood of normal seawater. The percentage of germination of carpospore in Chondrus crispus and the growth rate of the sporeling varied (Burns and Mathieson 1972) with the combined effects of temperature and salinity, but the maximum percentage of germination occurred at 11 °C and 35 ‰ salinity, Maximum growth occurred at 19 °C from 15 ‰ to 40 ‰, reaching a maximum at 40 ‰S, but showed a sharp drop of zero growth at 50 ‰ salinity.

In Gigartina stellata the optimum germination of the spores occurred (Burns and Mathieson 1972) at 30 ‰ S and 11 °C, whereas maximum growth rate occurred at 19 °C and 25 ‰, 30 and 35 ‰ salinity. A restricted tolerance to reduced salinities and temperature at 19 °C was observed in this species by Burns and Mathieson (1972), the spores

did not germinate at 15 o/oo, but unlike C. crispus showed some germination and growth at 50 o/oo. salinity.

Burns and Mathieson (1972) have further reported that some seaweeds could tolerate relatively low salinities under conditions of reduced temperature. For e.g., the carpospores of Gigartina stellata, showed germination and growth at 11° C but showed no germination and growth at a temperature of 19° C.

Salinity has been found to affect rates of photosynthesis and respiration. It has been shown to affect the amount of extracellular carbohydrates diffusing out of some algae (Fogg 1966). In some species of Ulva and Fucus the rate of photosynthesis is doubled when salinity is decreased by a third (from 35 o/oo to about 10 o/oo salinity), whereas some algae e.g. Enteromorpha sp., Fucus vesiculosus and Porphyra laciniata, do not show significant changes in respiration rates with salinity fluctuations, but other algae such as F. serratus and Laminaria digitata show enhanced respiratory rates with decreasing salinity.

In pure cultures of Isochrysis galbana and Prymnesium parvulum the amount of extracellular polysaccharides produced by the algae was increased with reduced salinity. It is a well known fact that the amount of dissolved gases in seawater is higher under conditions of reduced salinities than at high salinities (Raymont, 1963).

Among the dissolved gases, Oxygen is the most important for algal survival. Basically algae are aerobic and photosynthetic organisms and therefore they require oxygen for respiration and CO_2 for photosynthesis. From the present findings of the dissolved oxygen in seawater, it is seen that dissolved oxygen ranging from 2.67 to 6.33 ml/l is favourable for the growth and sporulation of algae, Similarly pH ranging from 8.0 to 8.7 are suitable for the growth and sporulation and other reproductive activities in the seaweeds.

CHAPTER - 6

SUMMARY

Studies on sporulation of four commercially important red algae (sea-weeds) (agarophytes) namely Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis growing in the vicinity of Mandapam coast were carried out from October 1981 to September 1983. During the two years of study, fruiting behaviour in the natural population of these species was also investigated. Laboratory experiments were carried out with the four algae (sea-weeds) to collect information on seasonal aspects of spore production and diurnal variation of spore shedding. Detailed studies were made under laboratory conditions to know the effects of some selected environmental factors such as desiccation, salinity, temperature, light intensity and photoperiod on spore output in Gelidiella acerosa, Gracilaria corticata G. edulis and Hypnea musciformis. Hydrological data were also collected from the inter-tidal region around Mandapam area. The results obtained on all the above aspects are presented in this thesis.

Population of Gelidiella acerosa, Gracilaria corticata, G. edulis and Hypnea musciformis occurred throughout the year along the coast of Mandapam. Tetrasporic plants of the four species were observed in all the months of the year. During the period of this study carposporophytes of Gracilaria

corticata and G. edulis were seen continuously throughout the year, while in Hypnea musciformis they were found only in some months from Aug. 1982 to Sept. 1983 at Pudumadam. But at Kilakkarai the cystocarpic plants were observed almost throughout the year. Cystocarpic plants were not found in the population of Gelidiella acerosa.

Maximum output of tetraspores and carpospores were observed mostly on the first day of the experiment in the four red algae studied. The tetraspore output decreased from second day onwards and rhythmic liberation of carpospores with peak shedding of spores at intervals of different days was also observed. Under laboratory conditions tetraspore output was observed for a period of 6-14 days in Gelidiella acerosa ; 6-27 days in Gracilaria corticata ; 3-30 days in G. edulis and 3-23 days in Hypnea musciformis during different months of the year. Carpospore liberation was found for 6-30 days in Gracilaria corticata, 10-30 days in G. edulis and 2-24 days in Hypnea musciformis during the period of this investigation. Seasonal periodicity was not observed in the liberation of tetraspores and carpospores in the four algae studied and also marked seasonal changes were not found in the abundance of stichidia per gram fresh weight of the plant/thalli in Gelidiella acerosa occurring at Kilakkarai.

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Maximum output of tetraspores and carpospores were observed mostly on the first day of the experiment in the four red algae studied. The tetraspore output decreased from second day onwards and rhythmic liberation of carpospores with peak shedding of spores at intervals of different days was also observed. Under laboratory conditions tetraspore output was observed for a period of 6-14 days in Gelidiella acerosa ; 6-27 days in Gracilaria corticata ; 3-30 days in G. edulis and 3-23 days in Hypmea musciformis during different months of the year. Carpospore liberation was found for 6-30 days in Gracilaria corticata, 10-30 days in G. edulis and 2-24 days in Hypnea musciformis during the period of this investigation. Seasonal periodicity was not observed in the liberation of tetraspores and carpospores in the four algae studied and also marked seasonal changes were not found in the abundance of stichidia per gram fresh weight of the plant/thalli in Gelidiella acerosa occurring at Kilakkarai.

Diurnal periodicity in the liberation of tetraaspores with a prominent peak between 2 P.M. and 6 P.M. was observed in Gelidiella acerosa and there was no change in the time of peak shedding of spores during this study. A definite peak at one period of the day in the shedding of tetraspores and carpospores was not seen in Gracilaria corticata, G. edulis and Hypnea musciformis and maximum liberation of spores occurred in these three species from 10 P.M. to 2 P.M.

In the experiments conducted in the laboratory to study the effect of environmental factors, spore output declined with increase in the duration of exposure of fruiting thalli in shade and maximum number of spores were liberated from the plants mostly under submerged condition. The spore output varied in different salinities tested, and peak shedding of spores was seen in 30 ‰ S in Gracilaria edulis and Hypnea musciformis, at 40 ‰ S in Gelidiella acerosa and at 30 ‰ S and 40 ‰ S in Gracilaria corticata. The optimum salinity range for peak shedding of spores in all the four algae was 30-40‰S. Peak sporulation was observed at low light intensity of 500 lux in Gelidiella acerosa, Gracilaria corticata and G. edulis and at 1000 lux in Hypnea musciformis. Spore output decreased in high light intensities. Spore production varied in different temperatures with maximum spore output at 25 °C in Gelidiella acerosa, at 30 °C in Hypnea musciformis and at 25 °C and 30 °C in Gracilaria corticata and G. edulis.

The germination of tetraspores in Gelidiella acerosa and tetraspores and carpospores in Gracilaria corticata, G. edulis and Hypnea musciformis occurred throughout the year in the laboratory conditions. But under selected environmental factors in the laboratory, maximum number of dividing tetraspores in Gelidiella acerosa and tetraspores and carpospores in Gracilaria corticata, G. edulis and Hypnea musciformis occurred in submerged conditions, at salinities ranging from 20-40‰, light intensity from 500 to 3000 lux and temperature 25 to 30°C.

Mode of germination observed in Gelidiella acerosa was that of 'Gelidium type' and that observed in Gracilaria corticata, G. edulis and Hypnea musciformis was that of 'Dumontia type'.

In the sea water samples collected at bi-monthly intervals from October 1981 to June 1983 from the interfidal region at three localities in the vicinity of Mandapam, temperature ranged from 25.8 to 30.7 °C, salinity from 28.28‰ to 36.25‰, pH from 8.0 to 8.7 and dissolved oxygen from 2.97 to 6.18 ml/ litre. The atmospheric temperature recorded in the area varied from 26.0 °C to 31.5 °C.

The present study on sporulation in selected/red algae of economic importance, suggests that the submerged condition of the fronds, salinity from 25-35‰ ; temperature from 25-30 °C ; low to medium light intensity (500 to 3000 lux), complete darkness, short day as well as long day conditions are favourable for spore production, spore discharge, spore germination, development of sporelings to adult thalli in the species of the orders, Gelidiales and Gigartinales, occurring in the vicinity of the coasts of Mandapam.

TABLE:10 SEASONALITY OF SPORE PRODUCTION IN DIFFERENT MARINE SEAWEEDS

Species	Month of peak spore production	Spore type	Study Locality	Reference
Ag. laothamnion cordatum	Throughout the year	A, C&T	Visakhapatnam, India.	Umamaheswara Rao and Sreeramulu 1970
Ascophyllum nodosum	November to February	A & O	Roscoff, France	Knight and Parke 1950
Bonnemaisonia hamifera	September to October	T	Nova Scotia, Canada.	Chen et al 1969
Centroceras clavulatum	a) Throughout the year	T	Visakhapatnam, India.	Umamaheswara Rao and Sreeranulu 1970.
	b) January to June & October.	A & C		
Chondrus crispus	a) Winter	T	Nova Scotia, Canada.	Chen and McLachlan 1972
	b) Summer	C		
Constantinea subulifera	a) April & May	A	Friday Harbour	
	b) Autumn	C & T	California	Neushul and Powell 1964.

TABLE 10 SEASONALITY OF SPORE PRODUCTION IN DIFFERENT MARINE SEAWEEDS

Species	Month of peak spore production	Spore type	Study Locality	Reference
Cordylecladia erecta	February to April	C & T	Mediterranean Sea,	Feldmann 1967
Dictyota dichotoma	Throughout the year	A, O&T	Visakhapatnam, India.	Umamaheswara Rao and Sreeramulu 1970
Falkenbergia rufulanosa	November to January	T	Brittany, France.	Feldmann J & G 1942, 1952.
Fucus serratus	a) Spring & Summer	A & O	Roscoff, France	Knight and Parke 1950.
	b) July to December	A & O	Plymouth, British Isle	
Fucus vesiculosus	a) Spring	A & O	Roscoff, France	-do-
	b) April to July	♂ & ♀	Plymouth, British Isle	
Furcelaria fastigiata	December to January	C & T	British Isle	Austin 1960
Gelidiella acerosa	a) First shedding peak in April	T	India	Rao 1971 a
	b) Second peak in October to November			

TABLE:10(Contd) SEASONALITY OF SPORE PRODUCTION IN DIFFERENT SEAWEEDS

Species	Month of peak spore production	Spore type	Study Locality	Reference
Gelidium sp.	December	T	British Isles	Dixon 1959
Gelidium robustum	August to December	C & T	Baja,California	Guzman del Proo et al 1972.
Gigartina stellata	September to January	C	New Hampshire, U.S.A.	Burns and Mathieson 1972
Gracilaria verrucosa	December to January	C	India	Oza and Krishnamurthy 1967
Gracilaria verrucosa	a)March to September	C	Japan	Ogata et al, 1972
	b)April to September	T		
Himanthalia elongata	June	A & O	Isle of Man, British Isles.	Blackler 1956.
Liagora erecta	Throughout maximum growth period i.e. November to December	A & C	Visakhapatnam, India.	Umamaheswara Rao and Sreeramulu 1970.
Liagora visakhapatnamensis	Throughout maximum growth period i.e. November to December	A & C	-do-	-do-
Padina tetrastromatica	Throughout the year	A, O&T	-do-	-do-

TABLE:10 (Contd) SEASONALITY OF SPORE PRODUCTION IN VARIOUS SEAWEEDS

Species	Month of peak spore production	Spore type	Study Locality	Reference
Phyllophora crispa	a) September	A	British Isles and Canada.	Newroth 1972
	b) September to March	C		
	c) November to January	T		
Phyllophora heredia	a) October	A		
	b) October to December	C	-do-	-do-
	c) May to November	T		
P. pseudocer-anoides	a) June to July	A	British Isles and Canada.	Newroth 1972
	b) November to May	C		
	c) November to January	T		
Pikea californica	November to January	C	Baja, California	Scott and Dixon 1971
Rhodochorton floridulum	December tc January	T	British Isles	Knaggs 1967 a
Spyridia filamentosa	January to April	T	India	Krishnamurthy 1968.
Trailliella intricata	October to December	T	Japan	Chihara 1961.

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