GROWTH, REPRODUCTION AND SPORE OUTPUT IN *GRACILARIA FOLIIFERA* (FORSSKAL) BOERGESEN AND *GRACILARIOPSIS SJOESTEDTII* (KYLIN) DAWSON AROUND MANDAPAM

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ABSTRACT

Observations made for one year on the seasonal changes in growth, reproduction and spore output of *Gracilaria foliifera* and *Gracilariopsis sjoestedtii* are given. These red algae occurred only a few months during the year in the area of study. Maximum growth of *G. foliifera* was during April and of *G. sjoestedtii* was during September and January-March. Tetrasporophytes were more abundant than carposporophytes in *G. foliifera*, whereas in *G. sjoestedtii* carposporophytes occurred more. Maximum outputs of tetraspores and carpospores were recorded on the first day, and the period of peak shedding of spores coincided with the peak growth period of these seaweeds. There was, however, no definite rhythm of diurnal spore output.

INTRODUCTION

Gracilaria foliifera (Forsskal) Boergesen and *Gracilariopsis sjoestedtii* (Kylin) Dawson grow respectively in the sublittoral and infralittoral fringe zone of Mandapam (Umamaheswara Rao 1972a, b and 1973), but on the ecology of these red algae, or on their reproduction, we do not have much information. Hence, eclogical studies were made on the natural population of these seaweeds and the results obtained on the seasonal growth, fruiting behaviour, spore production and diurnal aspects of spore output for a period of one year are presented in this paper.

MATERIAL AND METHODS

Plants of *G. foliifera* from Rameswaram and *G. sjoestedtii* from Pamban and Kilakarai were collected at fortnightly intervals. Twenty to twenty-five plants were brought to the laboratory in sea water and used for growth, phenology and spore-liberation studies. The percentage frequencies of tetrasporophytes, carposporophytes and vegetative plants present in the samples were estimated. The lengths of 20 to 25 erect shoots were measured randomly from plants of different

generation to know the seasonal variation in the stature of tetrasporic, cystocarpic and vegetative plants and also of the total population. For estimating the relative abundance of different size classes in the population, the erect fronds measured were divided into the following groups:

	Group I	Group II	Group III	Group IV
G. foliifera	< 5 cm	5-10 cm	10-15 cm	> 15 cm
G. sjoestedtii	< 10 cm	10-20 cm	20-30 cm	> 30 cm

Fronds (3-4 cm long pieces) with well-developed tetrasporangial sori and mature cystocarps were used for estimating the spore production. They were cleaned and washed several times in sterile sea water and placed in petri dishes of 9 cm diameter each containing 50 ml of sterile sea water. The experimental sets were kept under a light source of 500 lux for 8:16 LD cycle. For collecting information on the seasonal spore output, the spores liberated in the petri dishes were counted after 24 h every day and, for diurnal spore output, spores liberated at 4 h intervals from 2 PM were counted. The method described by Umamaheswara Rao and Kaliaperumal (1983) was followed for counting the spores. Depending on the availability of teterasporic and cystocarpic plants, 2-4 experiments were conducted separately in a month for collecting data on seasonal and diurnal spore output. The fresh weights of the fronds were taken after completion of the experiments for computing the spore output per gram fresh weight of the plants.

Results

Seasonal growth cycle: Data collected on the seasonal growth behaviour of *G. foliifera* and *G. sjoestedtii* are plotted in Fig. 1 and 2, respectively. Population of *G. foliifera* occurred for 5 months, March to June and February. Plants were observed to have minimum length in June and maximum length in April (Fig. 1, A and 1, B). Maximum percentage of Group III and Group IV fronds occurred in the population in April (Fig. 1, C). This also suggests that maximum growth occurs in *G. foliifera* in April.

Plants of *G. sjoestedtii* occurred for 8 months at Pamban. Plants with minimum length were found in August and maximum length during September and January to March (Fig. 2, A and 2, B). Group II, III and IV fronds occurred in more numbers during the period September and January to March (Fig. 2, C). This indicates that peak growth of *G. sjoestedtii* at Pamban occurs in September and from January to March. At Kilakarai *G. sjoestedtii* occurred only for 5 months. Plants with minimum length were recorded in May and maximum length in March and in January-February (Fig. 2, D and 2, E). Maximum percentage of Group II, III and IV fronds occurred during March and January-

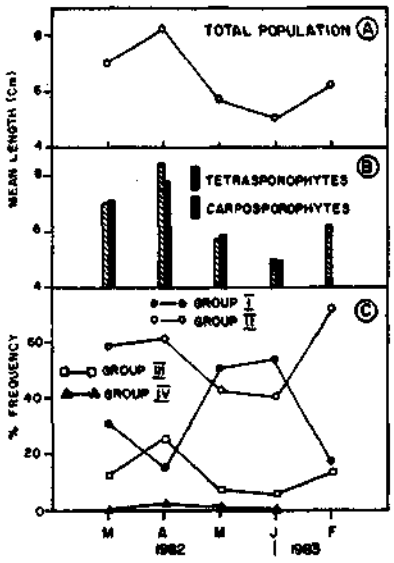

FIG. 1. Seasonal changes in length and frequency of four size classes of *Gracilaria foliifera*.

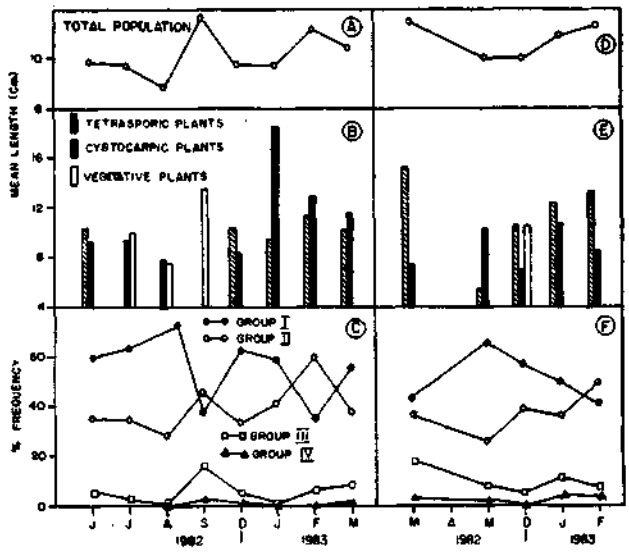

FIG. 2. Seasonal changes in length and frequency of four size classes of *Gracilariopsis sjoestedtii* growing at Pamban (A-C) and Kilakarai (D-F).

February. This clearly shows that in the plants of *G. sjoestedtii* occurring at Kilakarai maximum growth occurs during March and January-February and minimum growth in May.

Reproductive cycle: Monthly and annual mean values obtained on the abundance of tetrasporic, cystocarpic and vegetative plants of *G. foliifera* and *G. sjoestedtii* are presented in Table 1. In *G. foliifera* there was no vegetative plants and the samples consisted of tetrasporic and cystocarpic plants. Tetrasporophytes were more abundant than carposporophytes. In the population of *G. sjoestedtii* occurring at Pamban 77.2% (annual mean value) of plants were in fruiting condition. Cystocarpic plants were predominant over tetrasporic and vegetative plants. In *G. sjoestedtii* growing at Kilakarai 96.0% (annual mean value) of plants were in fruiting condition. Tetrasporophytes were more in number than cystocarpic and vegetative plants. There was no seasonal variation in the abundance of tetrasporic, cystocarpic and vegetative plants in *G. foliifera* and *G. sjoestedtii*.

Seasonal spore output: Figure 3 and 4 summarise the data obtained on tetraspore and carpospore output in *G. foliifera* and *G. sjoestedtii*, respectively. The spore shedding was seen to a maximum of 9 days in *G. foliifera* and 8 days in *G. sjoestedtii*, without any periodicity in the liberation of spores. Maximum output of spores occurred on the first day in both species. (The number of spores

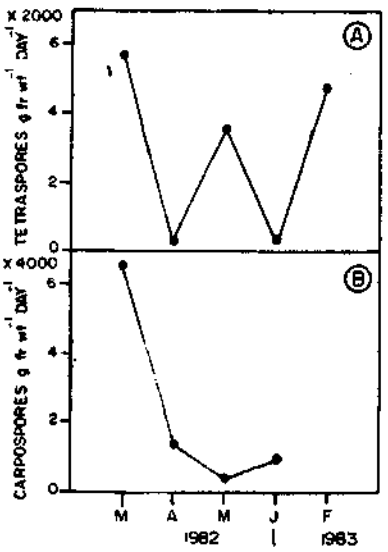

FIG. 3. Seasonal changes in tetraspore and carpospore output on the first day in *Gracilaria foliifera*.

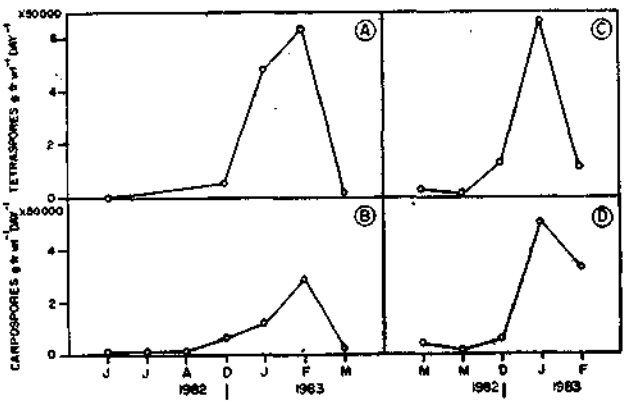

FIG. 4. Seasonal variations in shedding of tetraspores and carpospores on the first day in *G. sjoestedtii* occurring at Pamban (A and B) and Kilakarai (C and D).

liberated on the first day has been plotted in Fig. 3 and 4). In *G. foliifera* maximum quantity of spores were liberated in March. The quantity of tetraspores liberated during different months ranged from 500 to 11,508 (Fig. 3, A) and carpospores from 1,015 to 26,368 spores|g fr. wt. (Fig. 3, B). In *G. sjoestedtii* growing at Pamban peak output of spores occurred in February. The number of tetraspores varied from 1,197 to 3,15,636 (Fig. 4, A) and carpospores from 2,700 to 1,42,672 spores|g fr. wt (Fig. 4, B). In *G. sjoestedtii* growing at Kilakarai maximum production of spores was observed in January. The tetraspore output ranged from 52 to 3,27,791 (Fig. 4, C) and carpospore output from 14 to 2,52,151 spores|g fr. wt (Fig. 4, D).

Diurnal spore shedding: Results obtained on the study of diurnal periodicity in tetraspore and carpospore output for different months in *G. foliifera* are presented in Table 2 and in *G. sjoestedtii* from Pamban in Table 3 and from Kilakarai in Table 4. There was no definite diurnal periodicity with regard to the shedding of spores in both the species as the time of peak spore output varied in different months, though a maximum quantity of tetraspore and carpospore output in the latter species was found during day time, from 6 to 10 AM and from 10 AM to 2 PM in many months.

TABLE 1. *Percentage frequency of tetrasporic, cystocarpic and vegetative plants in the population of* Gracilaria foliifera *and* Gracilariopsis sjoestedtii.

	March'82	April	May	June	July	Aug.	Sept.	Dec.	Jan.'83	Feb.	March	Mean
Gracilaria foliifera												
Tetrasporic plants	88.0	90.0	84.0	84.0	—	—	—	—	—	100.0	—	89.2
Cystocarpic plants	12.0	10.0	16.0	16.0	—	—	—	—	—	0	—	10.8
Gracilariopsis sjoestedtii (Pamban)												
Tetrasporic plants	—	—	—	36.0	0	0	0	53.7	55.0	39.0	58.7	30.3
Cystocarpic plants	—	—	—	64.0	66.0	52.0	0	46.3	45.0	61.0	41.3	46.9
Vegetative plants	—	—	—	0	34.0	48.0	100.0	0	0	0	0	22.8
Gracilariopsis sjoestedtii (Kilakarai)												
Tetrasporic plants	74.0	—	12.5	—	—	—	—	60.0	61.7	70.0	—	55.6
Cystocarpic plants	26.0	—	87.5	—	—	—	—	20.0	38.3	30.0	—	40.4
Vegetative plants	0	—	0	—	—	—	—	20.0	0	0	—	4.0

TABLE 2. *Diurnal periodicity in the shedding of tetraspores and carpospores in* Gracilaria foliifera *in different months* (% spores|g fr wt).

	TIME					
Month	2-6 PM	6-10 PM	10 PM-2 AM	2-6 AM	6-10 AM	10 AM-2 PM
Tetraspores						
March 82	2.7	4.9	15.8	9.6	12.2	54.8
April	3.0	0	0	3.0	25.0	69.0
May	0	0	0	40.4	49.9	9.7
June	100.0	0	0	0	0	0
February '83	31.7	8.4	0.6	3.3	34.1	21.9
Carpospores						
March 82	1.2	2.0	9.9	3.3	38.0	45.6
April	0	0	5.3	54.7	18.9	21.1
May	0	0	2.6	71.8	23.2	2.4
June	0	0	84.7	0	0	15.3

TABLE 3. *Diurnal periodicity in the liberation of tetraspores and carpospores in* Gracilariopsis sjoestedtii *growing at Pamban* (% spores|g fr wt).

	TIME					
Month	2-6 PM	6-10 PM	10 PM-2 AM	2-6 AM	6-10 AM	10 AM-2 PM
Tetraspores						
December 82	0	0.1	0.7	18.7	30.9	49.6
January	0.1	0.1	7.3	26.4	43.2	22.9
February	0	0.2	2.5	3.0	42.1	52.2
March	0.6	0.3	0	1.0	54.1	44.0
Carpospores						
June 82	3.0	0.7	0.3	3.3	30.2	62.5
July	34.6	20.4	19.0	9.2	13.7	3.1
August	6.4	8.8	1.0	4.9	55.9	23.0
December	1.8	0.7	3.6	10.5	14.6	68.8
January 83	0.4	1.0	4.1	28.1	32.2	34.2
February	0.2	1.7	11.8	21.6	34.6	30.1
March	9.5	6.1	4.7	32.8	29.2	17.7

TABLE 4. *Diurnal periodicity of shedding of tetraspores and carpospores in different months in* Gracilariopsis *sjoestedtii occurring at Kilakarai* (% spores/g fr wt).

Month	TIME					
	2-6 PM	6-10 PM	10 PM-2 AM	2-6 AM	6-10 AM	10 AM-2 PM
Tetraspores						
March 82	6.6	3.9	7.3	3.1	24.7	54.4
May	0	0	0	0	0	100.0
December	0	0.5	0.7	16.3	70.0	12.5
January 83	0	0.1	8.1	25.4	64.1	2.3
February	0	0.1	0.1	38.6	36.4	24.8
Carpospores						
March 82	20.1	15.2	13.1	4.8	23.8	23.0
May	0	0	0	0	28.8	71.2
December	4.6	5.9	1.6	25.8	43.6	18.5
January 83	0	0.1	7.5	16.4	72.3	3.7
February	0	0	1.6	72.6	16.7	9.1

DISCUSSION

It may be seen from the foregoing account that the populations of *G. foliifera* at Rameswaram and *G. sjoestedtii* at Pamban and Kilakarai, which were reported to have been occurring in these localities throughout the year ten years before (Umamaheswara Rao 1973), have now so dwindled that they occur only for a few months every year. *G. foliifera*, which was having a half-yearly growth cycle now record considerable growth only in April every year.

The reproductive behaviour varies considerably in the two species. Tetrasporophytes are more abundant than carposporphytes in *G. foliifera*. In *G. sjoestedtii* cystocarpic plants are found in large numbers as observed by Umamaheswara Rao (1973). Periodicity in the production of reproductive structures was reported in *G. sjoestedtii* (Umamaheswara Rao 1973) and other members of Gracilariaceae, such as *Gracilaria verrucosa* (Ahmed 1966) and *Gelidiopsis variabilis* (Kaliaperumal and Umamaheswara Rao 1982). But in the present study on *G. foliifera* and *G. sjoestedtii*, reproductive structures are seen to occur without any seasonal changes.

Peak output of spores is found on the first day in *G. foliifera* and *G. sjoestedtii*, as observed in *Gelidiopsis variabilis* (Kaliaperumal and Umamaheswara Rao 1982), *Gracilaria corticata* (Mohan Joseph and Krishnamurthy,

1977) and *G. edulis* (Rama Rao and Thomas, 1974). The quantity of spores liberated is found to be more in *G. sjoestedtii* than in *G. foliifera*. The spore-producing capacity of *G. sjoestedtii* is comparable with *Gracilaria corticata* (Umamaheswara Rao 1976 and Mohan Joseph and Krishnamurthy 1977). Rhythmic liberation of carpospores with peaks at intervals of 4-5 days was reported in *G. corticata* (Mohan Joseph and Krishnamurthy 1977), *G. edulis* (Rama Rao and Thomas, 1974) and *G. verrucosa* (Oza and Krishnamurthy 1968). There is no such trend observed of carpospore output in *G. foliifera* and *G. sjoestedtii*. As observed in *G. corticata* (Umamaheswara Rao 1976 and Mohan Joseph and Krishnamurthy 1977), *G. edulis* (Rama Rao and Thomas 1974), *G. verrucosa* (Jones, 1959 and Oza and Krishnamurthy 1968) and *Gelidiopsis variabilis* (Kaliaperumal and Umamaheswara Rao 1982), peak shedding of spores is found at particular periods of the year in *G. foliifera* and *G. sjoestedtii* which coincided with the peak growth periods.

There is no definite rhythm in the daily spore output in *G. foliifera* and *G. sjoestedtii* as observed in *Iridophycus cornucopiae* (Fukuhara 1957). Seasonal variations in the diurnal periodicity of spores was reported in *Gelidium amansii* (Katada et al 1955 and Katada 1955), whereas marked seasonal changes are not observed in the diurnal rhythm of spore output in *G. foliifera* and *G. sjoestedtii*.

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