

GROWTH AND REPRODUCTION IN SOME SPECIES OF *GRACILARIA* AND *GRACILARIOPSIS* IN THE PALK BAY

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ABSTRACT

Growth and fruiting behaviour of the populations of *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariopsis sjoestedtii* are described based on the field studies conducted from January 1969 to June 1971 in the Palk Bay near Rameswaram. Populations of these three agar-yielding red algae have been observed throughout the year with two half yearly growth cycles, one from October/November to April and the other from May/June to September. The rate of growth was found to vary in the growth cycles. Plants with reproductive structures occur in *Gracilaria edulis* and *Gracilaria foliifera* in all months of the year and in *Gracilariopsis sjoestedtii* for a short period from November to March. Variations observed in the abundance of sexual, asexual and sterile plants and the abnormal features noticed in the reproductive behaviour of these three algae have been discussed.

INTRODUCTION

As very little is known on the growth and reproduction of many agar-yielding red algae in the natural habitats, investigations are being carried out on *Gracilaria* and other intertidal and subtidal algae growing in the vicinity of Mandapam. The present paper deals with the observations on growth and fruiting behaviours of *Gracilaria edulis* (Gmelin) Silva (= *G. lichenoides* J. Agardh), *Gracilaria foliifera* (Forsskal) Boergesen and *Gracilariopsis sjoestedtii* (Kyllin) Dawson in the period from January 1969 to June 1971.

MATERIALS AND METHODS

Plants of *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariopsis sjoestedtii* used in this study were collected at a station near Rameswaram (79°19' E, 9°17' N), which is situated on the Palk Bay side at about 20 km east of Mandapam. *Gracilaria edulis* and *Gracilaria foliifera* occur abundantly on dead coral stones in a shallow sublittoral lagoon. Plants of *Gracilariopsis sjoestedtii* were found on sandy areas of the coastline in the infralittoral fringe zone. Samples of these algae varying from 25 to 50 plants were collected once in

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a month. After measuring the length in the field, the plants were transported to the laboratory and information on the fruiting condition of the plants and percentage frequency of the sporophytic and gametophytic generations was collected (Umamaheswara Rao and Sreeramulu, 1970).

RESULTS

Seasonal growth behaviour

Seasonal variations observed in the mean length of *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariopsis sjoestedtii* from January 1969 to June 1971 are shown in Fig. 1. The minimum and maximum heights of the plants in the monthly samples along with the standard deviation to the mean values are plotted in this figure to show the size range in the populations. As shown in Fig. 1, increase in the mean length was found in *Gracilaria edulis* and *Gracilaria foliifera* from November or December and a large number of plants reached their maximum height during the period January to April. Soon after this growth to the maximum size there was a decline in the mean length in these two species of *Gracilaria*, particularly in May and June. This reduction in the height seems to be due to breakage or removal of the 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 each year, with an increase in height from July (Fig. 1). During October/November there was a considerable decrease in the average length of the plants. Degenerating basal parts and small plants with fresh shoots were seen in the samples collected in this two-month period. From the data collected for two and a half years it is clear that similar changes occur in the growth of *Gracilaria edulis* and *Gracilaria foliifera* year after year with two peak growth seasons per year.

In *Gracilariopsis sjoestedtii* the seasonal growth behaviour is irregular, though two peaks are discernable in the first year. Increase in growth was observed even from October onwards and fully grown plants were seen from November to February or March (Fig. 1). Thereafter mean length of the plants decreased till May. In the next four months growth cycle of *Gracilariopsis sjoestedtii* varied during the period of this study. In 1969 this alga was seen throughout the year with another small peak in growth between July and September (Fig. 1) as observed in *Gracilaria edulis* and *Gracilaria foliifera*. In 1971 the mean height increased from April onwards. But in 1970 *Gracilariopsis sjoestedtii* was apparently absent from June to September and the alga reappeared in the main growth season commencing from October onwards.

In order to study the distribution of different size or age groups in the population, monthly samples were divided into the following three groups, taking into account the maximum length of each alga:—

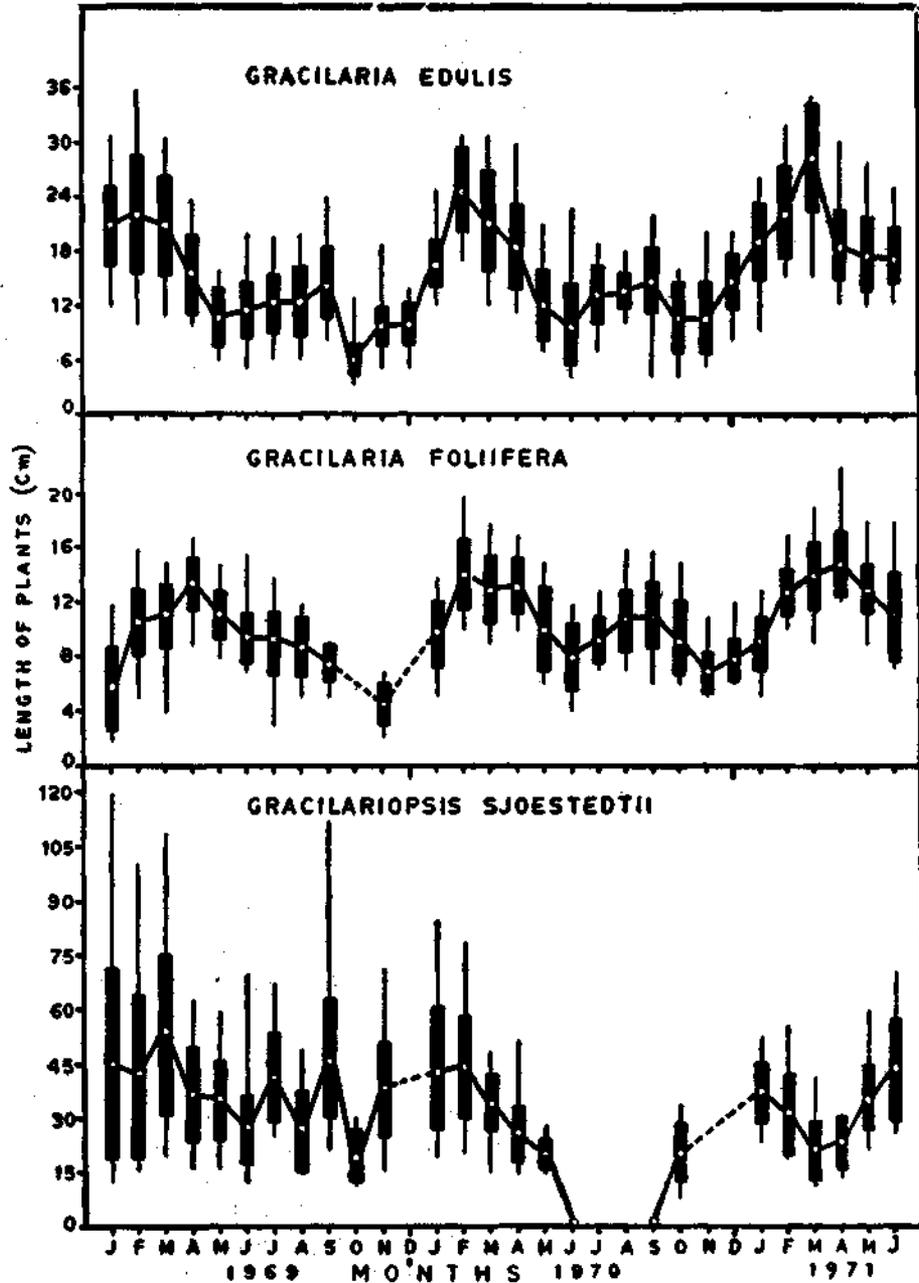


FIG. 1. Seasonal growth behaviour in *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariopsis sjoestedtii* during the period from January 1969 to June 1971. Standard deviations of the mean values are plotted as broad lines and the narrow lines show the size range in the monthly samples.

	Group I	Group II	Group III
<i>Gracilaria edulis</i>	Below 10 cm	11-20 cm	21 cm and above
<i>Gracilaria foliifera</i>	Below 6 cm	7-12 cm	13 cm and above
<i>Gracilariopsis sjoestedtii</i>	Below 20 cm	21-40 cm	41 cm and above

The percentage frequency distributions of these three size groups have been estimated and average values of Group I and Group III for the two years (1969 and 1970) are plotted in Fig 2 to show the general trend in the occurrence of "juveniles" (Group I) and "adult" plants (Group III) in different months of the year. From the data presented in Fig 2 it is evident that about forty to sixty percent (except in *G. foliifera* in June) of young plants of Group I occurs in two periods of the year i.e., during May/June and again in October/November months. Similarly Group III plants were found in two seasons (Fig. 2) and the percentage occurrence of this size group varied since many plants reached maximum height in the primary peak growth period from January to February-March and the secondary peak in growth observed between August and September was not prominent (Fig. 1). These observations indicate that the *Gracilaria* and *Gracilariopsis* species are not annuals and they have a half yearly growth cycle. The young plants or "juveniles" observed in the months of May-June and in October-November would grow to maximum size within four or five months.

Rate of Growth

An attempt has been made in this study to assess the rate of growth in the three red algae from the mean increase in length of the plants during the half yearly growth cycle. The duration of maximum increase in length recorded in different years, rate of growth estimated separately for the two growth seasons of the year and the mean growth rate per day are shown in Table 1. From this data it is evident that the mean rate of growth per day is 2-3 times higher (0.79-1.78 mm/day) in the primary growth season from October-November to April, than in the secondary growth season (0.35-0.46 mm/day) and the rate of growth in these two periods was more or less similar in different years (Table 1). In intertidal alga, *Gracilariopsis sjoestedtii*, the growth rate seems to be higher than in *Gracilaria edulis* and *Gracilaria foliifera* growing in the sublittoral habitats (Table 1).

Reproductive behaviour

Data collected on the percentage of sexual, asexual and sterile plants in monthly samples of *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariopsis sjoestedtii* are presented in Fig. 3. The mean values calculated for the years 1969 and 1970 are shown in Table 2. In *Gracilaria edulis* vegetative or sterile plants were predominant throughout the period of this study and 66.9 and 51.8% of sterile plants were found in the populations sampled in 1969 and 1970 respectively (Table 2). Tetrasporophytes occurred in all months except

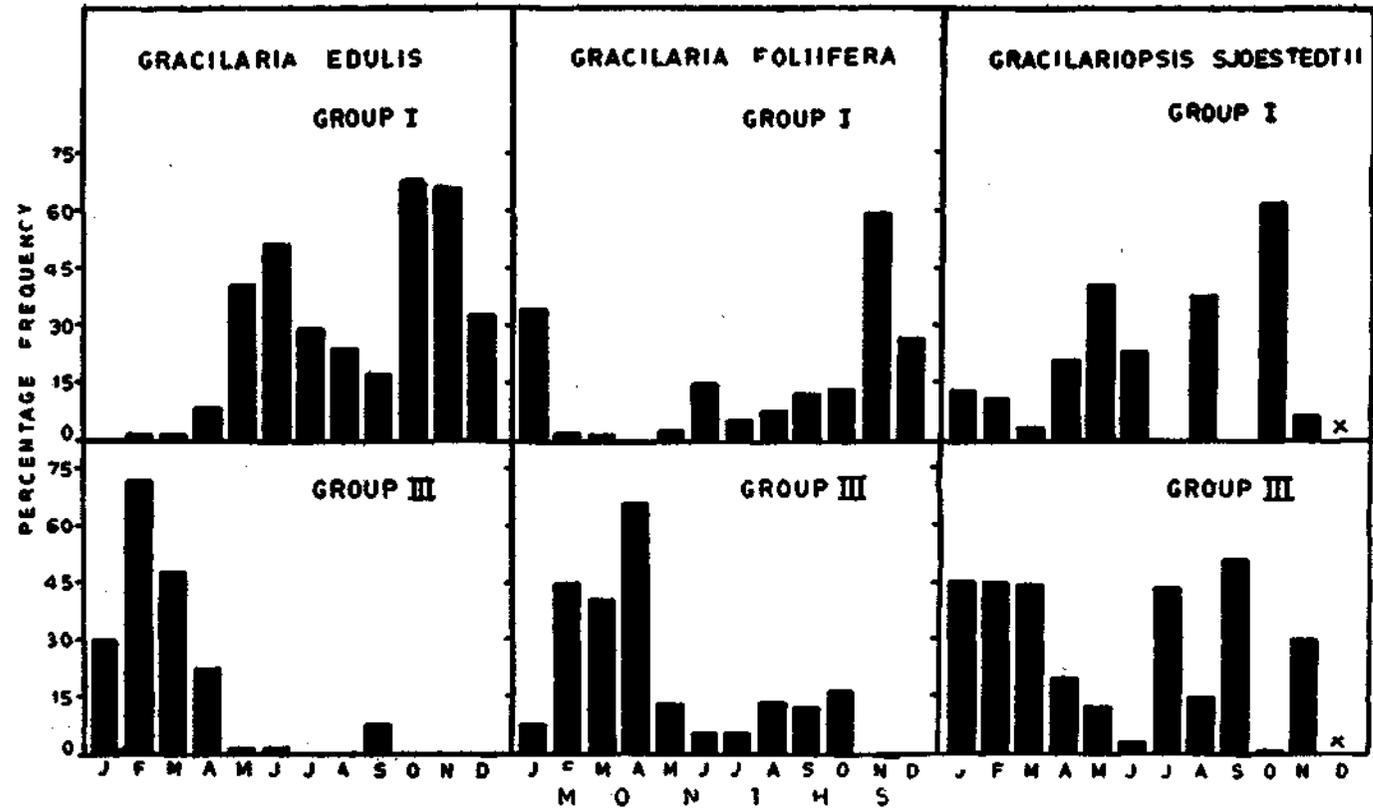


FIG. 2. Percentage frequency of the young (Group I) and adult plants (Group III) of *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariopsis sjoestedtii* in different months of a year.

TABLE 1. Total increase in mean length and growth rate estimated in the two growth seasons of *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariopsis sjoestedtii*

Alga	Growth season	Period of maximum increase in length		Total increase in mean length (cm)	Growth rate/day (mm)	Mean growth rate/day (mm)
<i>Gracilaria edulis</i>	Secondary	31-5-1969	to 17-9-1969	3.68	0.34	0.46
	Secondary	23-6-1970	to 16-9-1970	4.99	0.59	
	Primary	17-10-1966	to 24-2-1970	18.78	1.44	1.34
	Primary	29-11-1970	to 30-3-1971	14.91	1.23	
<i>Gracilaria foliifera</i>	Secondary	16-6-1969	to 17-9-1969	*	—	
	Secondary	23-6-1970	to 16-9-1970	3.00	0.35	0.35
	Primary	21-1-1969	to 22-4-1969	7.72	0.85	
	Primary	15-11-1969	to 24-2-1970	9.54	0.94	0.79
	Primary	29-11-1970	to 30-3-1971	7.19	0.59	
<i>Gracilariopsis sjoestedtii</i>	Secondary	16-6-1969	to 17-9-1969	*	—	
	Primary	17-10-1969	to 24-2-1970	25.40	1.95	1.78
	Primary	16-10-1970	to 27-1-1971	16.52	1.60	

* irregular growth

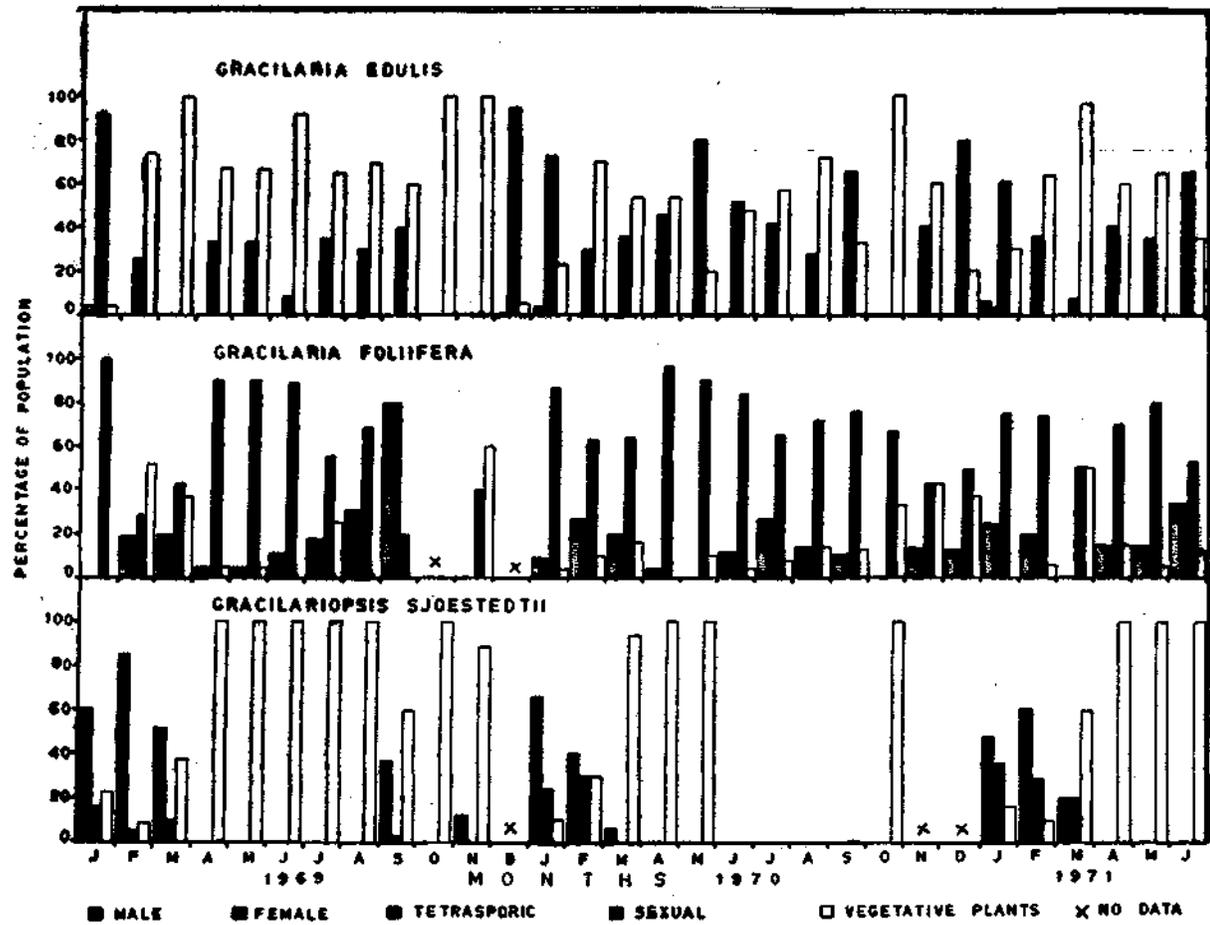


FIG. 3. Monthly variations of gametophytes, sporophytes and sterile plants in the populations of *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariaopsis sjoestedtii* during the period from January 1969 to June 1971.

in October or November. Antheridial and cystocarpic plants were, however, seen only in the month of January and only one or two plants were observed in the samples examined (Fig. 3, Table 2).

From the data presented in Fig. 3 and Table 2 it can be seen that the reproductive behaviour in *Gracilaria foliifera* is different in many respects from that of *Gracilaria edulis*. Both sexual and asexual plants were seen almost throughout the year. Yearly means given in Table 2 indicate that tetrasporic plants are abundant in the population and on an average 8.0 to 26.0% of sterile plants have been observed in 1969 and 1970. Another interesting feature observed in *Gracilaria foliifera* is the occurrence of more number of gametophytes alternating with sporophytic plants in the two half yearly growth cycles (Fig. 3). To show the changes in the abundance of the antheridial and cystocarpic plants in each growth season, percentage of the total gametophytes is plotted separately in Fig. 3.

In *Gracilariopsis sjoestedtii* definite fruiting periodicity was observed. Plants bearing reproductive structures were seen during the period from November to March (Fig. 3), while in the other months of the year only vegetative plants were found in the population. The percentage of cystocarpic and tetrasporic plants varied from one month to the other during the fruiting season

TABLE 2. Yearly mean of the sterile and different types of reproductive plants of *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariopsis sjoestedtii*

Alga	Year	Tetrasporophyte	Male	Cystocarpic	Sterile
<i>Gracilaria edulis</i>	1969	32.7%	0.4%	0.0	66.9%
	1970	47.8%	0.0	0.4%	51.8%
<i>Gracilaria foliifera</i>	1969	56.8%	6.4%	10.8%	26.0%
	1970	71.5%	6.4%	13.8%	8.3%
<i>Gracilariopsis sjoestedtii</i>	1969	3.1%	0.0	21.5%	75.4%
	1970	5.4%	0.0	10.1%	84.5%

and peak percentage of reproductive plants was seen during January and February (Fig. 3). Cystocarpic plants were more abundant (Table 2) than tetrasporophytes during the fruiting season and antheridial plants were not found in the collections of this alga. Because of the absence of male plants this alga has been tentatively identified as *Gracilariopsis sjoestedtii* (Umamaheswara Rao, 1971). In 1969 plants with reproductive bodies were however, seen in the month of September (Fig. 3), coinciding with the second growth cycle and all plants examined in October 1969 were in vegetative condition. In the following year also plants remained in vegetative condition in the month of October

(Fig. 3). These findings clearly indicate that the reproductive cycle of *Gracilariopsis sjoestedtii* commences from November each year and ends in the month of March. If the conditions are favourable for the growth of this intertidal alga in the other months of the year, (as observed in 1969 Fig. 1) another fruiting season can be seen for one month in the next half yearly growth cycle.

DISCUSSION

The present observations on the natural populations of *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariopsis sjoestedtii* growing in the Palk Bay at Rameswaram clearly show that these members of the Gracilariaceae occur throughout the year with a half yearly growth cycle. Analysis of the monthly samples further suggests that maximum number of young plants occur in May-June and again in October-November and they grow to maximum length within four or five months. The rate of growth, however, varied in the two half yearly growth cycles. A more marked or primary peak in growth was found in *Gracilaria edulis*, *Gracilaria foliifera* and *Gracilariopsis sjoestedtii* between January and February-March and a less conspicuous or secondary peak in growth between August and September (Fig. 1).

Ecological studies carried out on *Gracilaria corticata* and *Enteromorpha compressa*, growing on the Gulf of Mannar and Palk Bay sides near Mandapam, have demonstrated that the seasonal growth behaviour of these algae vary with the local changes in the tidal emergence and submergence and other environmental factors (Umamaheswara Rao, 1970). In the present study also it was observed that the water level of the lagoon where *Gracilaria edulis* and *Gracilaria foliifera* grow, decreases gradually from May to September due to mean sea level changes and monsoonal winds. The intertidal alga, *Gracilariopsis sjoestedtii*, is exposed to air for longer periods during the same time and it is also covered by sand because of the sand movement in the area. These changes in the environment may be responsible for the slow growth rate and for the small peak in growth observed between May and September in the sublittoral species of *Gracilaria edulis* and *Gracilaria foliifera* and also for the irregular growth behaviour observed in *Gracilariopsis sjoestedtii*, which occurs at a higher level than the two *Gracilaria* species (Fig. 1).

The reproductive behaviour varied considerably in each of the three members of the Gigartinales studied. Records available in literature show that sexual plants are predominant in members of Gigartinales and Cryptonemiales (Fritsch, 1945). In the three algae studied here cystocarpic plants are abundant only in *Gracilariopsis sjoestedtii* (Fig. 3, Table 2), whereas in *Gracilaria edulis* and *Gracilaria foliifera* tetrasporophytes were found in large numbers than the sexual plants.

Two definite fruiting periods were observed in *Gracilariopsis sjoestedtii*, corresponding with the half yearly growth cycles, when this alga was found

throughout the year (Fig. 3). The duration of fruiting extended upto five months in the main growth season and seasonal variations were also noticed in the reproductive plants within the fruiting period. As observed in this alga periodicity in the production of reproductive structures was recorded in *Gracilaria verrucosa* growing in the Chilka Lake (Ahmed, 1966), in the gametophytes of *Centroceras clavulatum* (Umamaheswara Rao and Sreeramulu, 1970) and in *Sargassum wightii* and *Turbinaria conoides* (Umamaheswara Rao, 1969). On the other hand in *Gracilaria edulis* and *Gracilaria foliifera* reproductive structures were seen throughout the year without any seasonal changes in the gametophytic and tetrasporic plants. Though some alteration of gametophytic and tetrasporic plants was seen in the half yearly growth cycles of *Gracilaria foliifera* (Fig. 3), a large percentage of plants were found in sterile condition, especially in *Gracilaria edulis*. These variations in the fruiting behaviour of *Gracilaria* species may be due to propagation of plants by vegetative means.

The present observations in the natural habitats further reveal the occurrence of certain irregularities in the normal pattern of life cycles such as the occurrence of one or two sexual plants of *Gracilaria edulis* in one month (Fig. 3) and absence of male plants in the populations of *Gracilariopsis sjoestedtii*. Similar abnormal conditions have been recorded in other species of *Gracilaria*. Ahmed (1966) reported the absence of antheridial plants in *Gracilaria verrucosa*. Recently Krishnamurthy *et al.* (1969) published an account on the development of cystocarpic plants from the carpospores of *Gracilaria edulis* and *Gracilaria corticata*. All these findings do not agree with the accepted pattern of life-history in *Gracilaria* and *Gracilariopsis*. Detailed culture studies on the Indian species of *Gracilaria* and *Gracilariopsis* are very essential to verify the reproductive behaviour of the plants observed in the field.

Taking into account the mode of growth, the rate at which plants grow to maximum height and also the reproductive behaviour of these three agar-yielding red algae it may be mentioned that the maximum growth periods from January to March and August to September are suitable for harvesting the plants of *Gracilaria edulis* and *Gracilaria foliifera* on a commercial scale. As reproductive structures occur throughout the year and plants grow to harvestable size within four or five months, two harvests per year may not affect the populations of *Gracilaria edulis* and *Gracilaria foliifera* in the natural habitats. From *Gracilariopsis sjoestedtii* only one crop can be obtained per year since the seasonal aspects of growth are irregular and fruiting plants occur for five months from November to March. The optimum period for collecting this alga is between February and March.

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