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Growth, Phenology & Spore Shedding in *Gracilaria arcuata* var. *arcuata* (Zanardini) Umamaheswara Rao & *G. corticata* var. *cylindrica* (J. Agardh) Umamaheswara Rao (Rhodophyta)

N KALIAPERUMAL, V S K CHENNUBHOTLA*, S KALIMUTHU & J R RAMALINGAM
Regional Centre of Central Marine Fisheries Research Institute, Mandapam Camp 623 520

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Maximum development of plants occurs in the intertidal region at Kilakarai, southeast coast of India, during March-April and Jan.-Feb. in *G. arcuata* var. *arcuata* and from Nov. to Feb. in *G. corticata* var. *cylindrica*. Tetrasporic plants are abundant almost throughout the year in both algae. Peak shedding of spores occurs during the maximum growth period in *G. arcuata* var. *arcuata* while seasonal variations are not observed in the discharge of spores in *G. corticata* var. *cylindrica*. Monthly output of tetraspores and carpospores varies from 43 to 28,291 and from 10 to 40,055 spores g^{-1} fr wt in *G. arcuata* var. *arcuata* and *G. corticata* var. *cylindrica* respectively. There is no definite rhythm in diurnal output in these algae.

The agar yielding red algae *Gracilaria arcuata* var. *arcuata* and *G. corticata* var. *cylindrica* have been reported from Kilakarai in the Gulf of Mannar near Mandapam[1]. Information on growth and reproduction of these agarophytes is not available for their use as source of raw material for the manufacture of agar. Besides, the natural resources of the Indian agarophytes are also insufficient to meet the demand of agar industries and hence their cultivation is essential. In order to assess the mariculture potential of these two species growth, fruiting cycle, seasonal and diurnal spore output have been studied.

Materials and Methods

Plants (10 to 25) of *G. arcuata* var. *arcuata* and *G. corticata* var. *cylindrica* were collected randomly at fortnightly intervals (March 1982 - Feb. 1983) during the spring tide periods from the rocks situated in the intertidal region at Kilakarai (70°47'E, 9°12'N), southeast coast of India. The materials collected were brought to the laboratory in seawater and used for growth analysis and spore output. The reproductive and vegetative or undeterminable plants from the samples were sorted by examining under a binocular microscope. The percentage frequencies of sexual, asexual and vegetative plants in the population were estimated. The length of 20 to 25 erect shoots were measured randomly from each plant to find out the seasonal changes in the stature of fronds of tetrasporophytes, carposporophytes, vegetative plants and also 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 considering the maximum length (cm) of each species:

	I	II	III	IV
G. arcuata var. *arcuata*	< 10	10-20	20-30	> 30
G. corticata var. *cylindrica*	< 4	4-8	> 8	—

Tetrasporic and cystocarpic fronds of 3-4 cm length without epiphytes were used for estimating the spore production. The material selected were washed thoroughly many times in sterile seawater and placed in petri dishes (9 cm diam.). The petri dishes were filled with 50 ml of sterile seawater and kept under a light source of 500 lux under 8:16 LD cycle in the laboratory at room temperature. Daily output of tetraspores and carpospores were estimated[2] up to maximum of 9 d. Maximum shedding of tetraspores and carpospores occurred on the first day in both plants. Hence data obtained on the first day of spore liberation was finally plotted to follow the seasonal changes in the spore production. Information on diurnal changes in spore shedding was collected at different intervals of time from 1400 hrs. Depending on the availability of tetrasporic and cystocarpic plants, 2 or 4 experiments were conducted separately in a month for collecting data on seasonal and diurnal spore output. The fresh weight of fronds was taken after completion of the experiments for computing seasonal changes in spore output per gram fresh weight of plants.

*Central Marine Fisheries Research Institute, Cochin 682 018

Results and Discussion

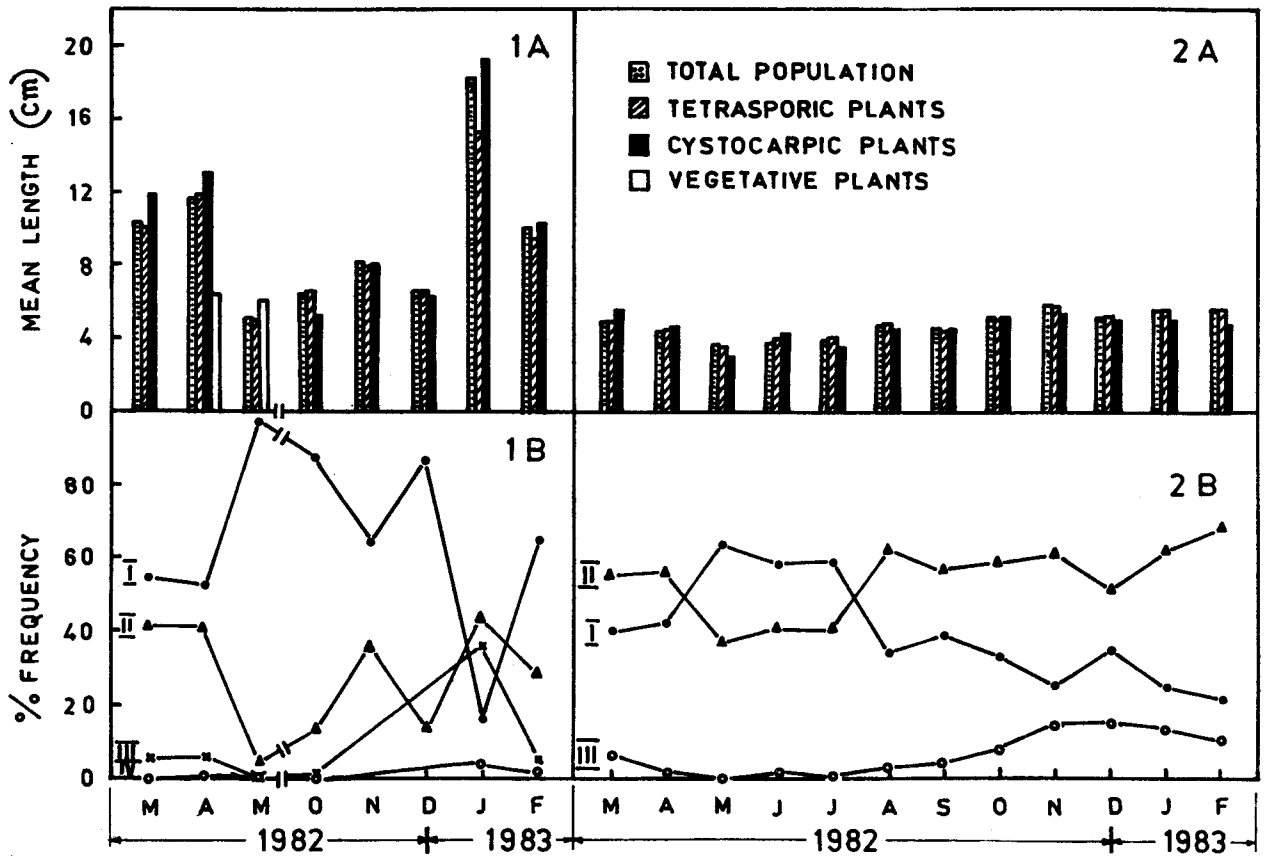
Plants with maximum length are observed during March-April and Jan. - Feb. in *G. arcuata* var. *arcuata* (Fig. 1A and B) and from Nov. to Feb. in *G. corticata* var. *cylindrica* (Fig. 2A and B) with a unimodal growth cycle in a year. This growth pattern with a single peak growth period in a year agrees with the growth behaviour of *Gelidiopsis variabilis*, a member of Gigartinales growing at Visakhapatnam Coast[3]. The growth behaviour of the present species varies from other members of Gigartinales growing at Mandapam area such as *Gracilaria corticata*[4], *G. edulis*, *G. foliifera* and *Gracilariopsis sjoestedtii*[5] where 2 peak growth periods in a year are reported with a half yearly growth cycle.

Results on phenology indicate that tetrasporophytes are predominant in the population over cystocarpic plants (Table 1) and in this aspect these 2 red algae agree with the fruiting behaviour of *Gracilaria edulis* and *G. foliifera*[5]. Vegetative plants occur only for 2 months in *G. arcuata* var. *arcuata* and they are absent in *G. corticata* var. *cylindrica*. Male plants are not found in both species during the entire period of this investigation. Periodicity in the production of reproductive structures is recorded in *Gracilaria verrucosa* growing in Chilka lake[6], *Gracilariopsis sjoestedtii* growing at Rameswaram[5] and *Gelidiopsis variabilis* occurring at Visakhapatnam coast[3]. But in the present species reproductive structures occur

Table 1—Percentage Frequency of Different Plants in the Population of *G. arcuata* var. *arcuata* and *G. corticata* var. *cylindrica*

Month	*G. arcuata* var. *arcuata*			*G. corticata* var. *cylindrica*	
	T	C	V	T	C
March'82	66.0	34.0	–	82.0	18.0
April	72.0	26.0	2.0	90.0	10.0
May	81.2	–	18.8	88.0	12.0
June	–	–	–	84.0	16.0
July	–	–	–	84.0	16.0
Aug.	–	–	–	80.0	20.0
Sept.	–	–	–	66.0	34.0
Oct.	81.0	19.0	–	84.0	16.0
Nov.	86.0	14.0	–	92.0	8.0
Dec.	92.2	7.1	–	78.0	22.0
Jan.'83	43.3	56.7	–	90.0	10.0
Feb.	35.0	65.0	–	96.1	3.9
Mean	69.7	27.7	2.6	84.5	15.5

Plants: T = Tetrasporic; C = Carposporic; V = Vegetative



Figs 1 and 2 —Seasonal changes in (A) length of erect fronds in total population and different generations and (B) percentage frequency of various size classes of erect fronds in *G. arcuata* var. *arcuata* (1) and *G. corticata* var. *cylindrica* (2) [Size class groups as in text]

without any seasonal changes as observed earlier[5].

Maximum shedding of tetraspores and carpospores is seen on the first day of liberation in *G. arcuata* var. *arcuata* and *G. corticata* var. *cylindrica* and it agrees with the results on carpospore output in *Gracilaria edulis*[7] and *G. corticata*[8] and tetraspore output in *Gelidiopsis variabilis*[3]. The spore producing capacity in the present algae is low when compared with *Gracilaria corticata*[8,9]. Rhythmic liberation of carpospores with peaks at intervals of 4-5 days is observed in *Gracilaria verrucosa*[10], *G. edulis*[7] and *G. corticata*[8]. But such a periodicity in shedding of carpospores is not found in the present study. Seasonal variations in shedding of spores in *Gracilaria corticata*[8,9], *G. edulis*[7], *G. verrucosa*[10,11] and *Gelidiopsis variabilis*[3] are reported with peak activity of sporulation at particular periods of the year. Similarly peak output of the tetraspores and carpospores occurs in *G. arcuata* var. *arcuata* during March and Jan. - Feb. (Fig. 3A), the period at which the plants attain their maximum growth. Though discharge of spores is seen in all months of the year in *G. corticata* var. *cylindrica*, seasonal variations are not found in the liberation of spores (Fig. 3B) and there is no correlation between the spore shedding and growth cycle in this alga.

Periodicity in the daily liberation of spores has been reported in *Gracilaria corticata*[9] and *Gloiopeltis tenax* and *G. furcata*[12]. Irregular behaviour is observed in

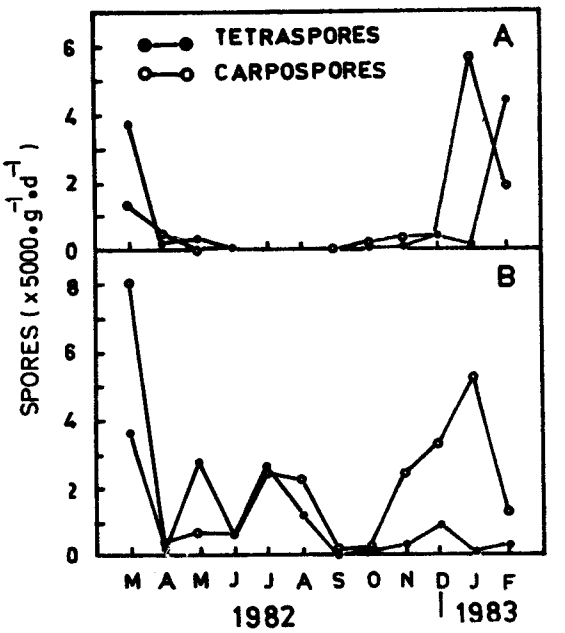


Fig. 3—Seasonal variation in tetraspore and carpospore output on the first day in *G. arcuata* var. *arcuata* (A) and *G. corticata* var. *cylindrica* (B)

Table 2—Diurnal Periodicity in the Liberation of Tetraspores and Carpospores in *G. arcuata* var. *arcuata* and *G. corticata* var. *cylindrica* in Different Months

[Values represent % spores.g^{-1} fr wt]

	Tetraspores						Carpospores					
	A	B	C	D	E	F	A	B	C	D	E	F
	G. arcuata var. *arcuata*											
March '82	0	0	8.2	20.5	36.2	35.1	0	0	19.8	19.1	37.9	23.2
April	29.7	29.6	18.7	9.7	6.9	5.4	13.2	12.9	16.8	6.1	14.9	36.1
May	0.9	1.2	1.2	50.5	36.2	10.0	0	2.6	42.3	34.9	20.2	0
Nov.	0	0	42.7	4.9	52.4	0	0	0	0	0	19.5	80.5
Dec.	22.2	14.1	17.0	8.4	18.6	19.7	81.6	0	0	0	0	18.4
Jan. '83	0	1.6	8.5	22.8	59.8	7.3	0	0	6.3	57.8	33.3	2.6
Feb.	0.2	0.4	4.9	72.6	15.8	6.1	0.2	0.5	2.5	46.4	14.7	35.7
	G. corticata var. *cylindrica*											
March '82	0	0	1.8	44.1	30.9	23.2	0	0	14.9	31.2	29.5	24.4
April	0	0	11.4	3.7	61.7	23.2	0	0	15.6	32.3	31.7	20.4
May	0.6	7.5	15.0	20.5	25.2	31.2	0	1.6	5.5	54.3	16.5	22.1
June	0	0	0	0	0	100.0	0	0.1	0	73.0	17.5	9.4
July	0	0	0	26.4	30.5	43.1	0	0	30.9	34.9	29.5	4.7
Aug.	3.6	2.5	0	26.7	16.8	50.4	0.2	0.2	18.1	49.8	24.1	7.6
Sept.	—	—	—	—	—	—	0	0	3.6	17.8	74.2	4.4
Oct.	0	0	0	100.0	0	0	9.9	0	65.8	24.3	0	0
Nov.	0	0	21.6	0	42.0	36.4	12.7	5.5	8.3	11.0	26.7	35.8
Dec.	0	0	3.1	47.5	47.7	1.7	0	0	32.9	27.7	26.0	13.4
Jan. '83	0	1.0	27.0	59.8	6.9	5.3	0	2.1	70.4	9.2	11.5	6.8
Feb.	18.1	0	4.8	0.8	51.7	24.6	0	0	0	26.6	20.5	52.9

Time (hrs) : A = 1400-1800; B = 1800-2200; C = 2200-0200; D = 0200-0600; E = 0600-1000; F = 1000-1400

the diurnal spore output of both the species studied (Table 2) in different months.

The present information on growth, reproduction and spore liberation suggests that a single harvest of these species in a year during Nov. to Feb. may not disturb the natural population.

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