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Seasonal Growth, Reproduction and Spore Shedding in *Gracilaria corticata* J. Agardh of the Visakhapatnam Coast

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Seasonal phenomena in the life cycle of *Gracilaria corticata* occurring in the intertidal region of Visakhapatnam coast were followed from December 1973 to April 1976. The alga was available throughout the year, with two half-yearly growth cycles, reaching its peak in June-July and November, December/January. Reproductive plants were observed throughout the year more abundantly than vegetative plants. Many carpospores and tetraspores were shed within 24 hr, between 2 AM and 6 AM in all the months, reaching peak liberation in December–February and August–October.

Key Words: Growth, Reproduction, Spore shedding, *Gracilaria corticata*, Visakhapatnam

Introduction

The ecology of growth and reproduction in several species of *Gracilaria* has been studied by Causey et al. (1946) and Jones (1959). However, there seems to be no such attempt in respect of *Gracilaria corticata* except for the limited information provided by Umamaheswara Rao (1972, 1976) from Mandapam coast, Mohan Joseph and Krishnamurthy (1977) and Oza (1979) from Veraval coast. This species grows profusely forming bands on the rocky substratum in the intertidal region along the Visakhapatnam coast. As a part of the study on the autecology of some Gigartinales of economic importance, observations on the growth, reproduction and sporulation made in *Gracilaria corticata* are presented in this paper.

Material and Methods

Large accessible boulders occur with dense growth of *Gracilaria corticata* at stations I and III described by Umamaheswara Rao and Sreeramulu (1964). From these stations, 30 randomly distributed plants were collected every spring tide at fortnightly intervals and sorted out into male, female, asexual and vegetative plants, and their percentage composition was determined. Length of 15 to 20 erect fronds of each category was determined to study mean length of

plants in each category and in population. Also frond lengths below 5 cms (Group I) and above (Group II) were determined to study their relative abundance monthly from December 1973 to April 1976.

Seasonal variation in the basal cover of this alga was determined by the quadrat method described by Umamaheswara Rao and Sreeramulu (1964). A brass frame of 25 cm^2 quadrat subdivided into 25 squares was used for observations from 10–15 marked quadrats on the rock.

Spore liberation in the laboratory was followed by the methods given by Umamaheswara Rao (1976); Umamaheswara Rao and Subba Rangaiah (1980, 1981) and Subba Rangaiah et al. (1975). Each time experiments were started at 6 PM in Petridishes and under illumination of 1500 lux from a flourescent lamp for 8 hr from 10 AM to 6 PM. After that fresh weight of the tetrasporic thalli and the number of cystocarps occurring on the thalli were noted. The spore output was expressed as tetraspores/g fr. wt./day or carpospores/cystocarp/day. To know the daily liberation of tetraspores and carpospores and also to study the seasonal changes in spore shedding, two experiments were conducted every month from December 1973 to April 1976.

The diurnal changes in the liberation of tetraspores and carpospores were studied in the samples collected at 10 A M 2 P M and 6 P M separately by changing the Petridishes at four hour intervals in each case. Five such experiments were made to know the influence of time of collection on the diurnal periodicity.

Results

No variation between two stations in the growth and distribution of *Gracilara corticata* was evident (figure 1). Algal populations occurred throughout the year. The length of the fronds increased during May reaching maximum in June-July, declined during August-September, and then again increased during October, attaining full size in November to December/January. Thereafter, it again decreased significantly up to March or April. Similar growth trend, viz., with two maxima and two minima was observed during the entire study period, indicating the prevalence of two growth seasons per year. The growth behaviour of sexual, asexual and vegetative plants was similar to that observed in the entire population (figure 1B & C).

Figure 1D shows the seasonal fluctuations in the abundance of fronds. The small new fronds (Group I) were abundant during March-April (May) and September-October. The well developed fronds (Group II) were in abundance in December-January (65–89%) and June-July (44–50%).

Two peaks were evident in the development of basal cover, 54–70% cover of the alga was observed in December-January and 40–56% in June-July (figure 1E). Minimum basal cover was in March–May and September-October. The rate of growth in mean length of *G. corticata* (table 1) in primary season is 2.0 to 2.5 times greater than in secondary season.

Fruiting Behaviour

Of the total plants examined, about 77% were in fruiting, of which *ca.* 17% were of cystocarpic, *ca.* 16% of antheridial and *ca.* 45% of tetrasporic plants (table 2). There were no significant changes in the abundance of sexual and asexual generations during different months.

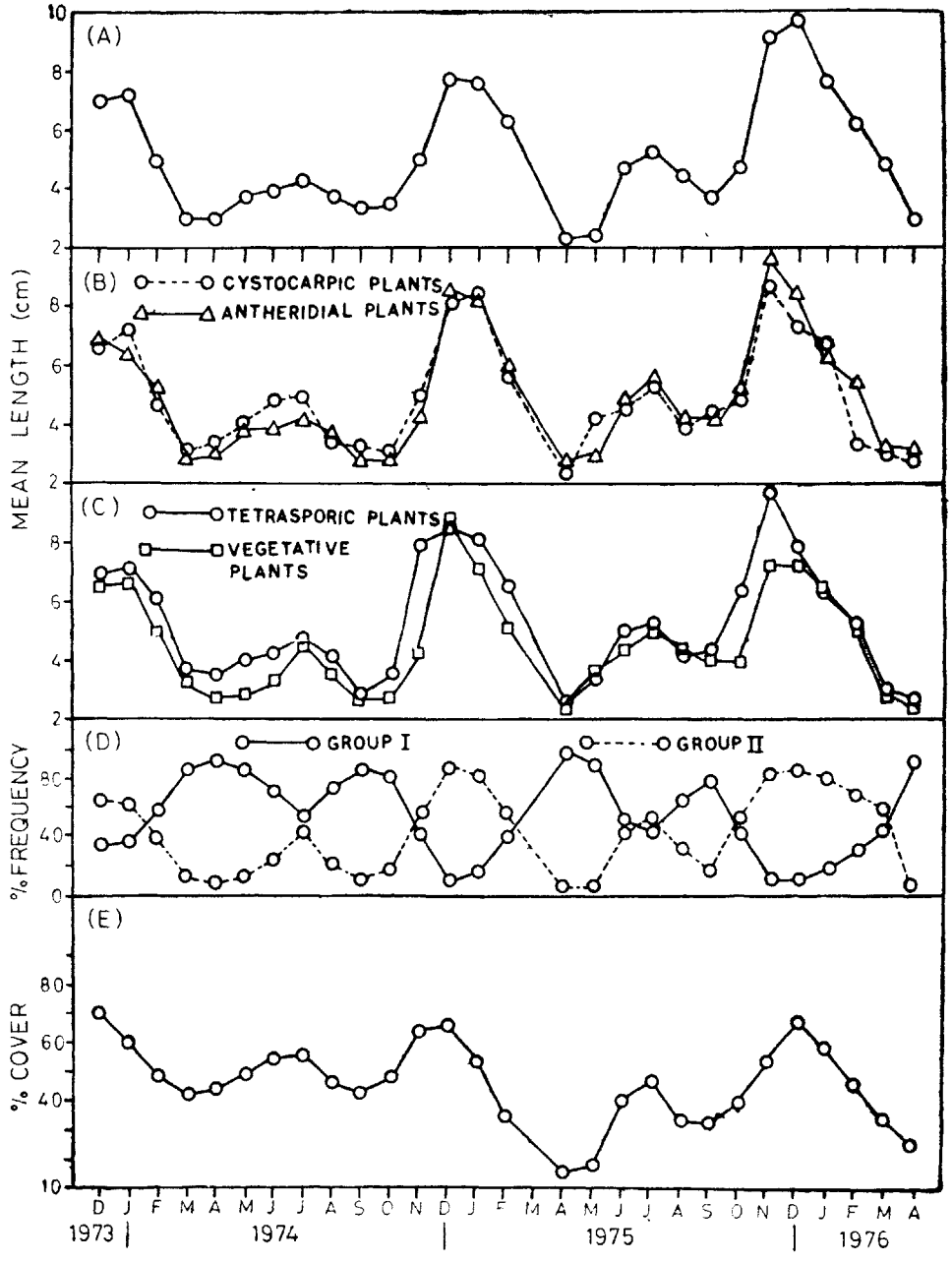
(A)
(B)
CYSTOCARPIC PLANTS
ANTHERIDIAL PLANTS
(C)
TETRASPORIC PLANTS
VEGETATIVE PLANTS
(D)
GROUP I
GROUP II
(E)
MEAN LENGTH (cm)
% FREQUENCY
% COVER
D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
1973
1974
1975
1976

Figure 1 (A–E)

Table 1 *Increase in the mean length and growth rate estimated in the two growth seasons of* Gracilaria corticata

	Growth season	Period of maximum increase in length	Total increase in mean length mm	Growth rate/day mm	Mean growth rate/day mm
Gracilaria corticata	Secondary	6-3-74 to 21-7-74	13	0.09	0.18
	Secondary	9-4-75 to 23-7-75	29	0.27	
	Primary	19-8-74 to 30-12-74	42	0.32	0.42
	Primary	25-8-75 to 20-12-75	61	0.53	

Table 2 *Percentage frequency of sexual, asexual and vegetative plants in the population of* Gracilaria corticata

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Mean
Cystocarpic plants													
1973-74	12	18	10	12	5.5	10	20	18	17.5	16	18	12	14.09
1974-75	15	20	14	—	10	8	15	18	13.0	13	18	22.2	15.10
1975-76	26	22	28	20	12	—	—	—	—	—	—	—	21.60
Antheridial plants													
1973-74	16	13	11	12	7.5	10	10	15	15.5	16	18	16	13.33
1974-75	15	19	15	—	12	15	17	15	16.0	16	14	17.3	15.54
1975-76	19	20	16	10	16	—	—	—	—	—	—	—	16.20
Tetrasporic plants													
1973-74	32	51	42	41.5	52	60	56	48.5	52	52	49	52	49.00
1974-75	40	44	48	—	37	45.5	50	53.0	51	43.5	37.5	41.5	44.54
1975-76	34.5	42	40	50.0	40	—	—	—	—	—	—	—	41.30
Vegetative plants													
1973-74	40	18	37	34.5	35	20	14	18.5	15	16	15	20	23.58
1974-75	30	17	23	—	41	31-5	18	14	20	27.5	30.5	19	24.82
1975-76	20.5	16	16	20	32	—	—	—	—	—	—	—	20.90

Spore Output

Figure 2 shows maximum shedding of both types of spores on the first day and the output decreased rapidly from the 2nd day onwards. Shedding of carpospores occurred for 5 to 10 days and tetraspores for 3 days.

Seasonal Changes in Spore Output

Maximum spore output occurred within 24hr, therefore, these were used to study the seasonal changes in spore production. Figure 3 shows that the spores were shed in all months of the year. Tetraspore shedding was maximum in December-February, and August-October. The tetraspore production varied from 13,700 to 3,33,300 spores/g fr. wt./day. Peak production of carpospores was noted during January-February and in August. The carpospore output ranged between 300 to 3,100 spores/cystocarp/day.

Diurnal Periodicity

No change in the peak liberation of spores in tetra-sporic and cystocarpic plants collected in the morning, afternoon, evening hours was seen (figure 4), hence

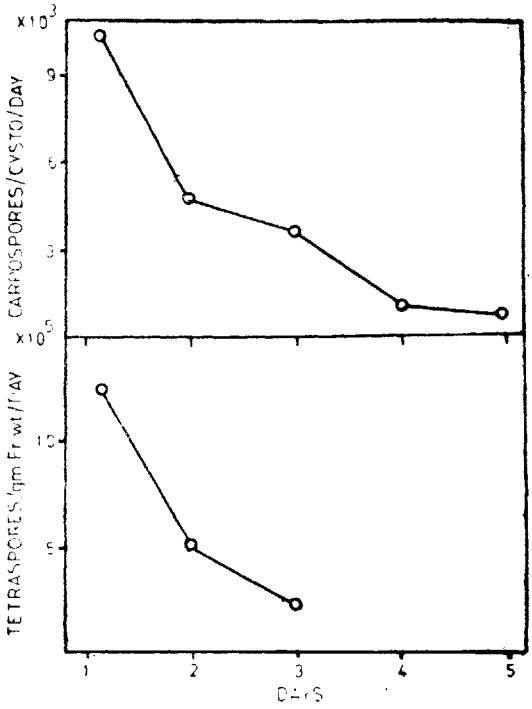

Figure 2

the time of collection of plants in a day had no effect on shedding time.

Diurnal periodicity in the liberation of spores in plants collected during different months are shown in figure 5. Since spore output varied seasonally, mean values of the data obtained for two years were expressed as percentages of spores liberated at different times of the day. In all the experiments conducted at different times of the day and in different months, the maximum number of tetraspores and carpospores shedding was seen during the early morning hours between 2 AM and 6 AM (figures 4 & 5)

Discussion

Present studies reveal that *Gracilaria corticata* occurs throughout the year on the Visakhapatnam coast, but is abundant in two seasons, thereby exhibiting two half-yearly growth cycles each with a separate spore-producing season. Bimodel growth curves were also found in *G. corticata*, *G. edulis* and *G. foliifera* growing in the vicinity of Mandapam (Tamilnadu) (Umamaheswara Rao 1972, 1973) and in *G. corticata* occurring on the coast of Veraval (Gujarat) (Oza 1979). Srinivasan (1946), on the other hand, reported peak development of *G. corticata* during January-February at Mahabalipuram, near Madras. In the other geographical areas where seasonal growth was studied on various species of *Gracilaria* (Causey et al. 1946, Jones 1959) single peak growth period was observed either in the population observed throughout the year or for a short period. The growth rate in *G. corticata* was less than the growth rate of *G. edulis*, *G. foliifera* at Mandapam (Umamaheswara Rao 1973). The local environmental conditions, especially the tidal behaviour, may be responsible for the changes observed in the growth cycles as already reported in the earlier studies (Umamaheswara Rao 1972, Rama Rao 1972).

At Visakhapatnam, the duration of submergence of inter-tidal region was more in the periods May-June and October-November (Umamaheswara Rao & Sreeramulu 1964). During same period rapid increase in growth rate of *G. corticata* was observed, suggesting the influence of tidal submergence on the growth and development of this alga. Sand movement on the shore is another factor on the Visakhapatnam coast which might effect plant growth (Umamaheswara Rao & Sreeramulu 1964). The small or secondary peak observed with slow growth rate in *G. corticata* may also be due to filling up of the beach and covering of boulders with sand at the lower part of the intertidal region between May and September.

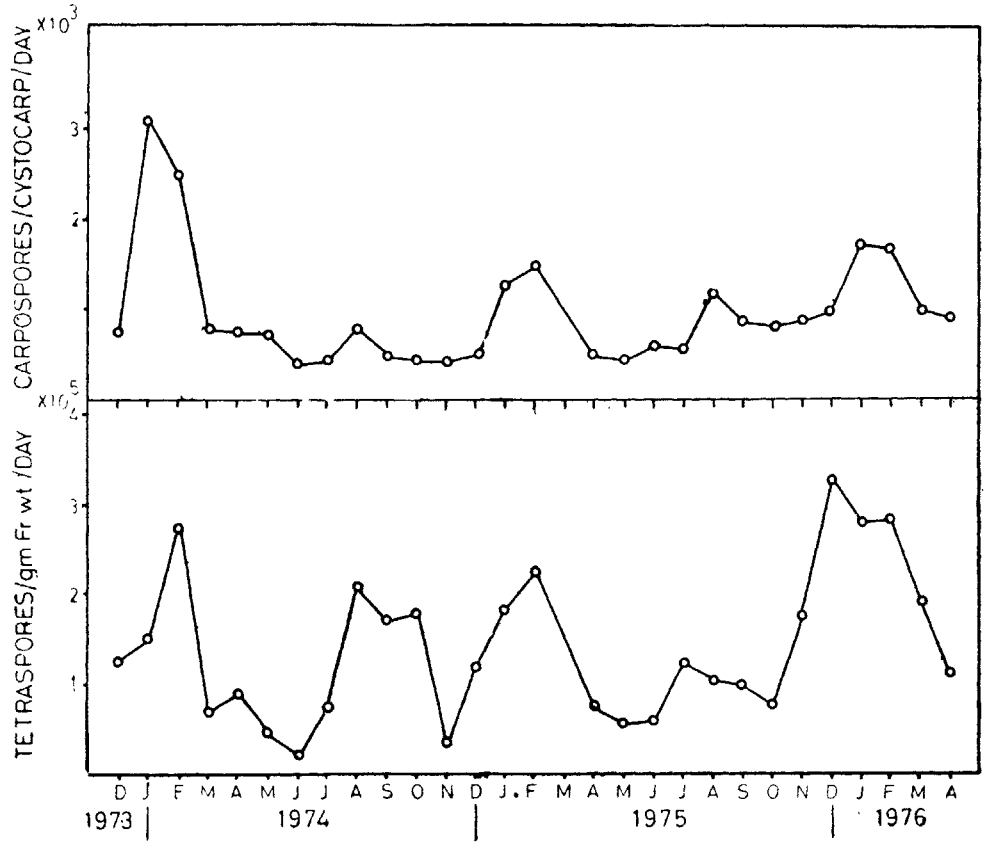

Figure 3

At Visakhapatnam coast tetrasporophytes and sexual plants of *G. corticata* occur in all months of the year (table 2) whereas Oza (1979) in the same species reported tetrasporic plants throughout the year, while the sexual plants occur seasonally on the coast of Veraval. In *G. verrucosa* and other species growing in different geographical areas, fertile plants were found for a few months (Oza & Krishnamurty 1968) but Jones (1959) reported them throughout the year in *G. verrucosa* with seasonal variation in their abundance. Present studies (table 2) reveal no seasonal variations in the abundance of fertile plants, which is similar to the observations made on *Gracilaria* species growing near Mandapam (Umamaheswara Rao 1973). Fritsch (1945) reported abundance of sexual plants were more than the asexual ones in Gigartinales, but in the present study, it is reverse. The occurrence of male, female and tetrasporic plants suggests triphasic life history in *G. corticata.*

Maximum shedding of tetraspores and carpospores seen on the first day (figure 2) is similar to the carpospore shedding in *G. edulis* (Rama Rao and Thomas 1974). But in *G. verrucosa* (Oza & Krishnamurty 1968) and *G. corticata* (Mohan Joseph & Krishnamurty 1977) carpospore discharge was seen on the second or third day. Small peaks were also not found at

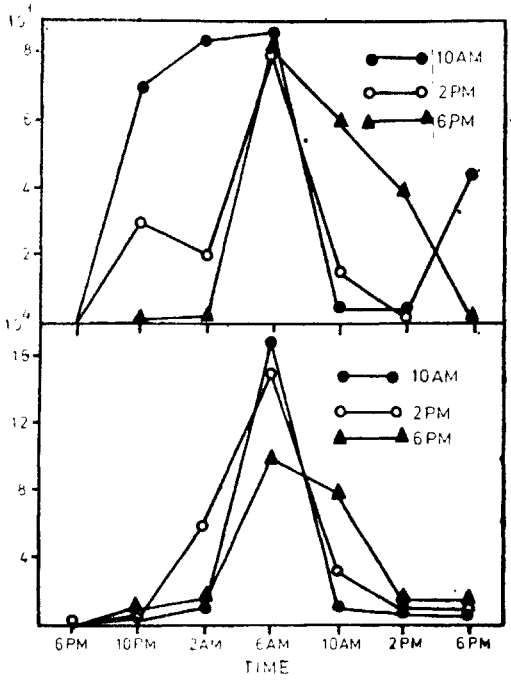

Figure 4

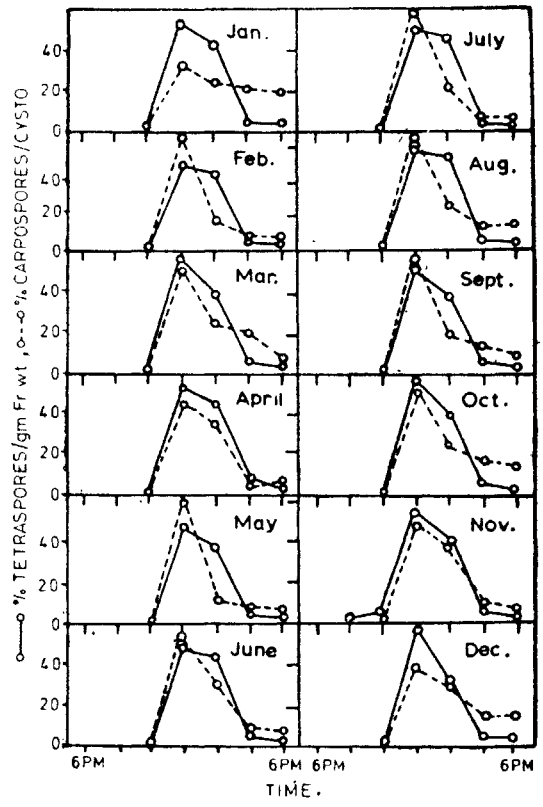

Figure 5

intervals of 4 to 5 days in the present study, unlike observations made by Mohan Joseph and Krishnamurty (1977).

In *G. corticata* occurrence of two peaks of spore liberation one in December–February/March and the other in August–October agree with the findings on *G. edulis* (Rama Rao & Thomas 1974), and *G. corticata* growing around Mandapam (Umamaheswara Rao 1976). In the other geographical areas where single growth peak was found and where fruiting plants occurred throughout the year, maximum shedding was reported in one season e.g., in *G. verrucosa* (Jones 1959), maximum production of spores were observed in July and August. In *Gelidiella acerosa*, the periodicity in the daily liberation of spores varies with the time of collection of the plants (Sreenivasa Rao 1971). But in *G. corticata*, time of its collection has no effect on the time of peak liberation of spores (figure 4).

It may be mentioned that *G. corticata* can be harvested twice in a year during its maximum growth period; June-July and November-December/January, just after peak liberation of spores to maintain its natural population.

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References

Causey N B, Prytherich J P, McCaskill J, Humm H J and Wolf F A 1946 Influence of environmental factors upon the growth of *Gracilaria confervoides*; *Duke. Univ. Mar. Sta.* **31** 9–24

Fritsch F E 1945 *The Structure and Reproduction of the Algae*; vol. II (London: Cambridge University Press)

Jones W E 1959 The growth and fruiting of *Gracilaria verrucosa* (Hudson) Papenfuss; *J. mar. biol. Ass. U.K.* **38** 47–56

Mohan Joseph M, Krishnamurty V 1977 Studies on the shedding of carpospores in *Gracilaria corticata*; *J. Ag. Seaweed Res. Utilization* **2** 1–8

Oza R M and Krishnamurty V 1968 Studies on carpospore rhythm of *Gracilaria verrucosa*; *Bot. Mar.* **11** 118–121

—— and ——1979 Studies in Indian *Gracilaria* III. Seasonal variation in growth and reproduction in *Gracilaria corticata* J. Ag. occurring on the coast of Veraval (Gujarat); *Proc. Intl. Symp. on Marine Algae of the Indian Ocean region* (in press) (abstract No. 18)

Rama Rao K 1972 Role of critical tide factor in the vertical distribution of *Hypnea musciformis* (Wulf) Lamour; *Proc. Indian natn. Sci. Acad.* **B38** 267–272

——and Thomas P C 1974 Shedding of carpospores in *Gracilaria edulis* (Gmel); *Silva. Phykos* **13** 54–59

Sreenivasa Rao P 1971 Studies on *Gelidiella acerosa* (Forsskal) Feldmann and Hammel. IV. Spore studies; *Bull. Jap. Soc. Phycol.* **19** 9–14

Srinivasan K S 1946 Ecology and seasonal succession of the marine algae at Mahabalipuram (seven Pagodas) near Madras; *Indian Bot. Soc.* MOP Iyengar Commemoration Volume 267–278

Subba Rangaiah G, Umamaheswara Rao M and Rao B G S 1975 Effect of salinity on spore shedding in *Gracilaria corticata*; *Curr. Sci.* **44** 717–718

Umamaheswara Rao M 1972 Ecological observations on some intertidal algae of Mandapam Coast; *Proc. Indian natn. Sci. Acad.* **B38** 298–307

—— 1973 Growth and reproduction in some species of *Gracilaria* and *Gracilariopsis* in the Palk Bay; *Indian. J. Fish.* **20** 182–192

—— 1976 Spore liberation in *Gracilaria corticata* J. Ag. growing at Mandapam; *J. Exp. mar. Biol. Ecol.* **21** 91–98

—— and Sreeramulu T 1964 An ecological study of some intertidal algae of the Visakhapatnam Coast; *J. Ecol.* **52** 595–616

—— and Subba Rangaiah G 1980 Effects of environmental factors on the shedding of tetraspores of some Gigartinales (Rhodophyta); *Proc. Symp. Coastal Aquaculture* (in press) (abstract No. 189).

——and—— 1981 Effects of environmental factors on the diurnal periodicity of tetraspores of some Gigartinales (Rhodophyta); *Proc. Xth Int. natl. Seaweed Symp.* 209–214