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## EFFECTS OF ENVIRONMENTAL FACTORS ON THE LIBERATION OF SPORES FROM SOME RED ALGAE OF VISAKHAPATNAM COAST

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**Abstract:** Experiments were conducted with tetrasporophytes of *Gelidium pusillum* (Stackhouse) Le Jolis, *Pterocladia heteroplatos* (Boergesen) Umamaheswara Rao & Kaliaperumal, and *Gelidiopsis variabilis* (Greville) Schmitz, to determine the effects of various environmental factors on the liberation of spores. The ability to liberate spores and the quantity of spores shed by these three red algae varied with the different environmental conditions tested. Submerged condition of the plants, long day condition at low illuminance, sea water of 30 to 40‰ salinity and 25 to 30 °C temperature were found to be favourable for maximum shedding of spores at Visakhapatnam. The variability observed in spore-shedding under short- and long-day conditions was considered to be due to the photosynthetic effect also noticed in the growth of certain red algae.

### INTRODUCTION

In order to understand the effects of diverse ecological conditions on spore liberation, detailed experimental studies have been made on red algae of Visakhapatnam coast, India. Results of the work done on some members of the Gigartinales have already been published (Umamaheswara Rao & Subbarangaiah, in press). The present paper summarizes the experimental data collected on *Gelidium pusillum* (Stackhouse) Le Jolis, *Pterocladia heteroplatos* (Boergesen) Umamaheswara Rao & Kaliaperumal, and *Gelidiopsis variabilis* (Greville) Schmitz.

### MATERIALS AND METHODS

Tetrasporophytes of *Gelidium pusillum*, *Pterocladia heteroplatos*, and *Gelidiopsis variabilis* were collected at different times of the year and used in the spore-shedding experiments. Small fruiting tufts of the first two algae with mature sori and stichidia of *Gelidiopsis* were selected and washed many times with sterile sea water. Two or three fruiting tufts or stichidia were placed in Petri dishes (5 cm diam.) containing 15-20 ml of sterile sea water. These Petri dishes with fertile thalli were used in all the experiments conducted in the laboratory.

Effects of desiccation were studied by blotting fruiting tufts or stichidia with cloth and exposing them to air for 15, 30, 45, 60, 90, and 120 min at room temperature in the

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laboratory ( $28 \pm 2^\circ\text{C}$ , and 67 to 80% r.h.) and for 5-min intervals directly in the sun up to 15 min ( $30 \pm 2^\circ\text{C}$ , and 56 to 78% r.h.). After exposure to air the fronds were then placed in Petri dishes containing sterile sea water and the spore output was determined. Fronds kept throughout the period of the experiment in submerged conditions served as controls. Data could not be obtained on stichidia of *Gelidiopsis* exposed to the sun.

A stock solution of 80‰ salinity, prepared by adding common salt to sea water, was diluted with distilled water and used for spore-shedding experiments at different salinities.

Desiccation and salinity experiments were conducted at 500 lux daylight fluorescent illumination under a 8:16 LD cycle. Influence of eight different illuminance values (0, 500, 1000, 1500, 2000, 3000, 4500, and 5500 lux) was tested under continuous illumination in a light chamber provided with 40 W Phillips daylight fluorescent lamps. The combined effects of day-length and illuminance were studied by subjecting the fruiting materials to 0:24, 8:16, 12:12, 16:8, 20:4, and 24:0 light and dark regimes. These experiments were conducted at 500, 2000, and 4500 lux with *Gelidium*; at 500 and 4500 lux with *Pterocladia*; and at 500, 2000, and 3000 lux with *Gelidiopsis*.

Data on the effect of temperature on spore-shedding were obtained exposing the Petri plates containing materials to nine different temperatures ranging from 0 to  $45^\circ\text{C}$ . Since temperature-controlled light chambers were not available, these experiments were conducted in a temperature-controlled dark incubator or deep freezer. For each factor ten replicates were used with *Gelidium* and *Pterocladia* and five replicates with *Gelidiopsis*.

All these experiments were conducted for 24 h. At the end of each experiment the liberated spores and sea water in each Petri dish were mixed thoroughly with a fine brush and the spore suspension transferred to a measuring jar. The volume of the spore suspension was adjusted to 20 or 25 ml using washings of the Petri dish or sterile sea water. A subsample of 1 ml of spore suspension was then pipetted into a plankton counting chamber and the spores present in all the squares of the chamber were counted under a binocular microscope. From the mean values of two counts and the total volume of the spore suspension, the spore output from the fruiting material was estimated. The number of sori present in the fruiting tufts of *Gelidium* and *Pterocladia* were noted to express the data as tetraspores liberated per sorus or stichidium.

Spore output varied within the samples collected in any month and also in different months of the year (Kaliaperumal & Umamaheswara Rao, 1982) due to differences in the formation and maturity of the fertile parts of *Gelidium*, *Pterocladia* and *Gelidiopsis*. The standard errors to the means plotted in Figs. 1–5, show these inherent variations in the materials used for this study.

## RESULTS

## DESICCATION

Results obtained in the desiccation experiments are shown in Fig. 1. In these experiments maximum tetraspore output was obtained from *Gelidium*, *Pterocladia* and

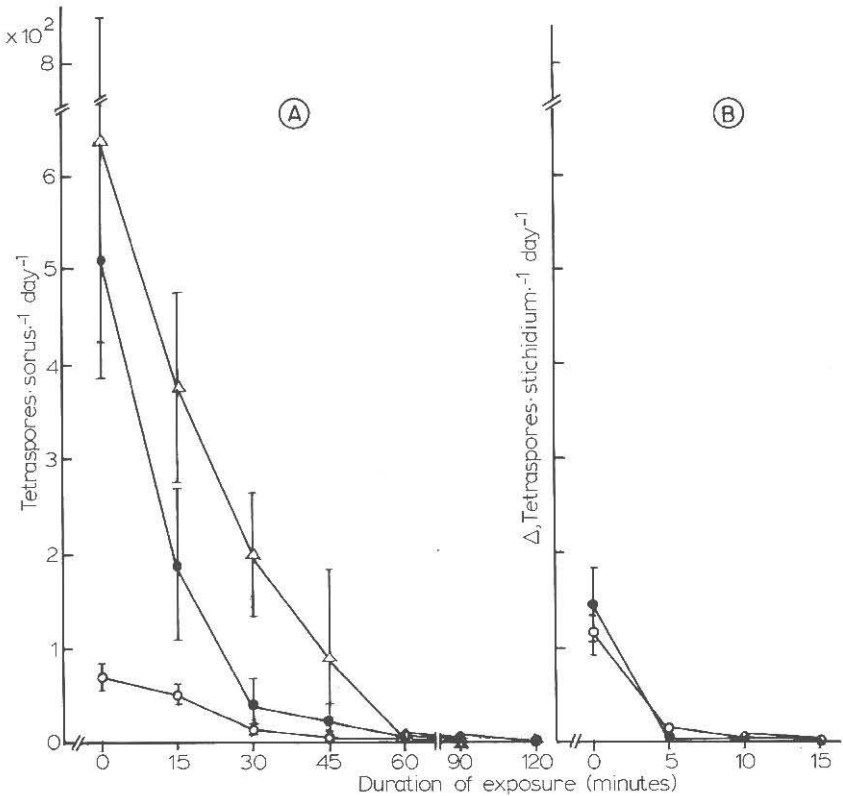


Fig. 1. Effect of desiccation on the shedding of spores from *Gelidium* (●), *Pterocladia* (○) and *Gelidiopsis* (△): A, thalli exposed to air at room temperature; B, thalli exposed to air in the sun; note breaks in axes.

*Gelidiopsis* kept under (control) submerged conditions (0 exposure). In plants exposed to air in the laboratory the spore output declined rapidly up to 30 min exposure and complete inhibition was seen after 90 min exposure in *Gelidium* and after 60 min in *Pterocladia* and *Gelidiopsis*. In the algae exposed for 5 min in the sun (Fig. 1), there was a sudden fall in spore liberation, indicating that the differences in temperature and relative humidity between areas protected and unprotected against the sun modify spore production in the red algae investigated.

## ILLUMINANCE AND PHOTOPERIOD

Peak discharge of spores was found in the three algae at 500 lux (Fig. 2). From 1000 lux the spore output decreased with increasing illuminance in *Gelidium* and *Gelidiopsis* and complete inhibition was seen in these algae at 5500 lux. In *Pterocladia* the peak output was at 500 lux, changes observed between 1000 and 3000 lux were not marked and lowest values were obtained at 4500 and 5500 lux (Fig. 2).

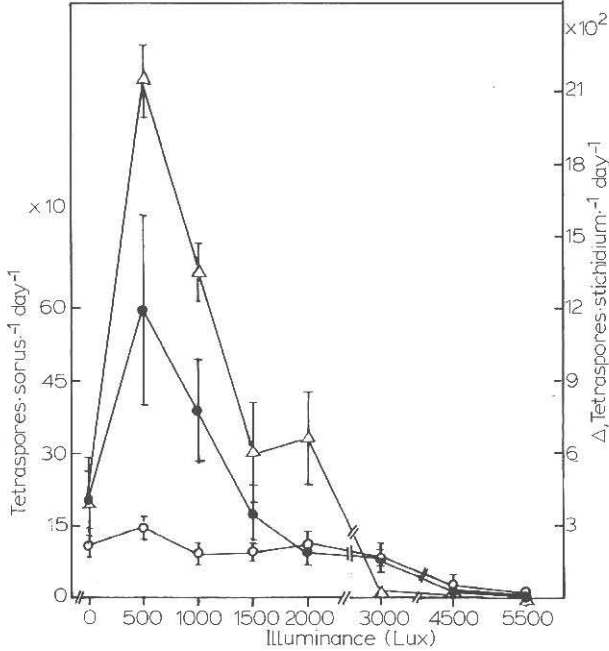


Fig. 2. Influence of illuminance on the liberation of spores from *Gelidium* (●), *Pterocladia* (○) and *Gelidiopsis* (Δ); note breaks in lower axis.

The combined effects of day-length (photoperiod) and illuminance are shown in Fig. 3. At 500 lux spore output increased gradually and peak shedding was observed under long day conditions i.e. between 16:8 and 24:0 LD regimes. At higher illuminance maximum shedding was seen under short day conditions. For instance between 2000 and 3000 lux maximum shedding was observed in *Gelidium* and *Gelidiopsis* at 8:16 LD cycle. At 4500 lux spore output was high in *Gelidium* and *Pterocladia* under 4:20 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 (Fig. 2). As mentioned in the methods section the variations in the mean values of spore-shedding observed in darkness (0:24 LD) are due to the use of materials collected at different times of the year.

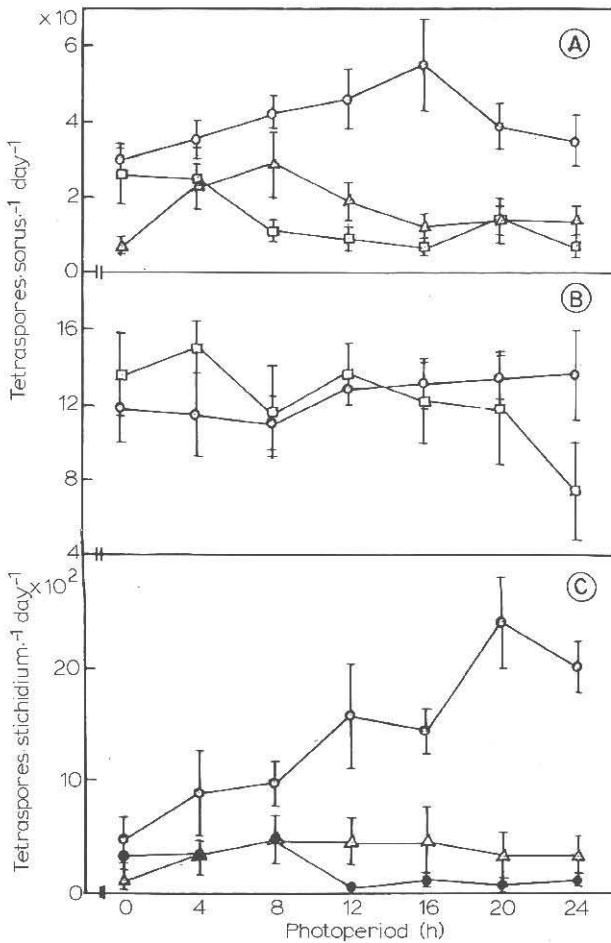


Fig. 3. Combined effects of illuminance and duration of light on the shedding of spores from *Gelidium* (A), *Pterocladia* (B), and *Gelidiopsis* (C): O, 500 lux;  $\Delta$ , 2000 lux;  $\bullet$ , 3000 lux;  $\square$ , 4500 lux.

#### SALINITY AND TEMPERATURE

Fig. 4 shows the results obtained on spore output in different salinities ranging from 0 to 70‰. In *Gelidium* and *Pterocladia* spore-shedding was found from 10 to 60‰ with peak discharge at 30‰. In *Gelidiopsis* spore-shedding was seen only in three salinities (20, 30, and 40‰) with the lowest value at 20‰ (Fig. 4); salinities < 20‰ completely inhibited spore shedding in this alga. Furthermore, at 40‰ salinity the spore output was more in *Gelidiopsis* than in *Gelidium* and *Pterocladia*.

The effect of thermal stress on spore liberation is shown in Fig. 5. Although these experiments were not conducted under low illuminance, the spore output varied at the different temperatures tested. In *Gelidium* spore output increased from 15 °C with peak

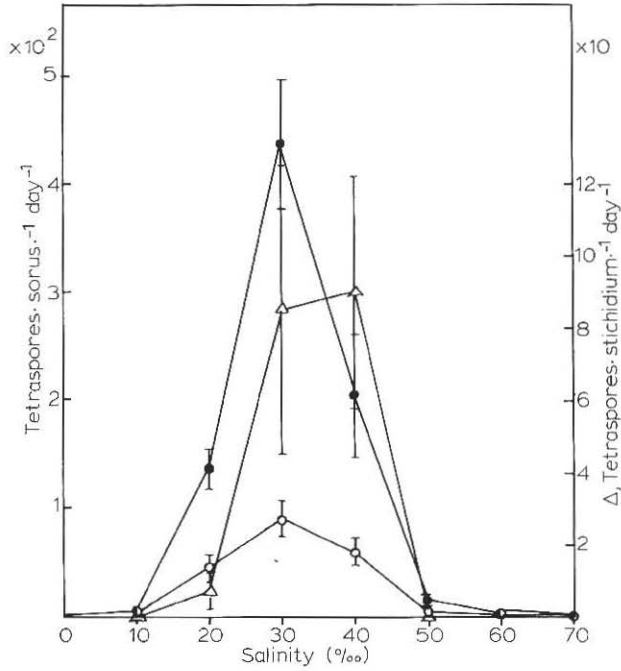


Fig. 4. Effect of salinity on spore output from *Gelidium* (●), *Pterocladia* (○), and *Gelidiopsis* ( $\Delta$ ).

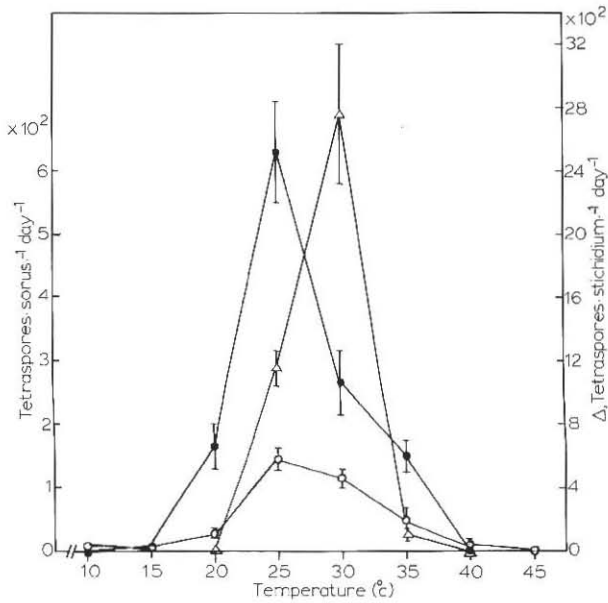


Fig. 5. Influence of water temperature on the liberation of spores of *Gelidium* (●), *Pterocladia* (○), and *Gelidiopsis* ( $\Delta$ ).

shedding at 25 °C. At 30 °C and 35 °C the spore output declined rapidly. In *Pterocladia* 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 (Fig. 5). Between 20 and 35 °C the changes observed in *Pterocladia* were similar to those of *Gelidium*, with peak discharge of spores at 25 °C. In contrast, in *Gelidiopsis* spore output was seen only at three temperatures (25, 30, and 35 °C) with the maximum at 30 °C. There was a sudden fall in the quantity of spores liberated by this alga at 35 °C (Fig. 5).

## DISCUSSION

On Visakhapatnam coast plants of *Gelidium*, *Pterocladia* and *Gelidiopsis* occur throughout the year in sheltered habitats of the infralittoral fringe zone. Observations made on the growth and reproductive phenology of these algae indicate a unimodal growth and reproductive cycle in *Gelidiopsis* with maximum development of fronds during October to January–February and peak reproductive activity between July and September (Kaliaperumal & Umamaheswara Rao, 1982). In *Gelidium* and *Pterocladia* less conspicuous seasonal changes were found in the growth and reproductive behaviour (unpubl. obs.).

Results of the present study when compared with the earlier work on spore discharge, clearly indicate that the effects and tolerance limits vary in different red algae. In *Gloiopeltis tenax* and *G. furcata* (Matsui, 1969) desiccation of the fronds accelerated spore liberation, whereas decrease in spore output was seen in *Gelidium*, *Pterocladia*, and *Gelidiopsis*, suggesting that the desiccation caused by tidal behaviour is not conducive to spore release in these red algae growing in the lower part of the intertidal region of Visakhapatnam coast. These findings agree with those for *Gelidium amansii* (Katada, 1955), *Gelidiella acerosa* (Sreenivasa Rao, 1971), *Gracilaria corticata*, and other members of Gigartinales (Umamaheswara Rao, 1976; Umamaheswara Rao & Subbarangaiah, in press).

In *Hypnea valentiae* maximum spore-shedding was seen at  $750 \pm 50$  lux (Umamaheswara Rao & Subbarangaiah, in press). The results obtained on *Gelidium*, *Pterocladia*, and *Gelidiopsis* at 500 lux also support the view that low illuminance is favourable for peak discharge of spores. The response observed in *Gracilaria* and *Gracilariopsis* species, however, differs from the above findings, since peak shedding was found in these algae in complete darkness (Umamaheswara Rao & Subbarangaiah, in press). When reviewing the scanty information available on the effects of light period on the growth and reproductive processes, Dixon (1970) pointed out that there were no clear cut examples in red algae showing the influence of the amount of light energy received by plants on the formation and release of reproductive bodies. The changes observed in the present attempt (Fig. 4) clearly suggest that the amount of light energy (mean daily illuminance) received by plants controls spore release. This type of variation in the discharge of spores observed under short and long day conditions has been described

by Dixon & Richardson (1970) as a photosynthetic effect. A similar photosynthetic effect has been reported by Murray & Dixon (1973) in the division of apical cells of *Pleonosporium squarulosum*.

In *Gloiopeltis* species no marked changes in spore output were found by Matsui (1969) in salinities ranging from 17 to 52‰. On the other hand, in *Gelidium*, *Pterocladia*, and *Gelidiopsis* species spore output varied in the low and high salinities tested, with peak shedding around 30‰. *Gelidium* and *Pterocladia* tolerate a wide range of salinities, while low salinities or estuarine conditions appear to be unsuitable for spore release in *Gelidiopsis* (Fig. 4). Suto (1950) observed shedding of tetraspores and carpospores of *Gelidium* in sea water of temperatures ranging from 20 to 24 °C. Matsui (1969) reported peak output of spores between 10 and 25 °C in *Gloiopeltis* species. In the present investigation undertaken in tropical waters, peak shedding of spores was found between 25 and 30 °C. Liberation of spores from 10 to 40 °C in *Gelidium* and *Pterocladia* and in the narrow thermal limit of 25 to 35 °C in *Gelidiopsis* also helps to explain the variations in the geographical distribution, especially the restricted distribution of *Gelidiopsis* in tropical waters.

From the above results, it may be concluded that submerged condition of plants, long day condition under low illuminance, sea water of 30 to 40‰ salinity and 25 to 30 °C temperature are favourable for the maximum liberation of spores in *Gelidium pusillum*, *Pterocladia heteroplata*, and *Gelidiopsis variabilis*. Although one must be very cautious while correlating the experimental data with the conditions existing in the field, the ranges of salinity and temperature observed for these red algae come close to the annual ranges of salinity and surface-water temperature at Visakhapatnam (Ganapathi & Satyanarayana Rao, 1962; Umamaheswara Rao & Sreeramulu, 1964).

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