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Effect of Environmental Factors on Oospores Shedding and Diurnal Periodicity in *Sargassum Ilicifolium (*Turner) C.Agardh. Along The Visakhapatnam Coastline, East Coast of India

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Abstract: ***Sargassum ilicifolium (Turner)*** **C.Ag. was observed throughout the year in the two areas studied i.e., Gangavaram and Pudimadaka of around Visakhapatnam coast. Oospore shedding from this brown alga was studied in respect of effect of environmental factors such as desiccation, salinity, Photon flux density, temperature, photoperiod and also on diurnal periodicity during December, 1995 to May, 1998. Maximum number of oospores were released when fronds were in submerged condition, exposed to dark condition and at 30 ‰ salinity, 9µEm^{-2}s^{-1} Photon flux density, 25^{o}c temperature, Photoperiod 12:12 (L-D cycle). In the present study neither acceleration nor delay in the peak shedding of oospores in *S.ilicifolium* was found 2:00-6:00 hours.**

Keywords: ***Sargassum ilicifolium*****, Oospores shedding, Environmental factors, Photoperiod, Diurnal periodicity, Gangavaram and Pudimadaka.**

I. INTRODUCTION

Sargassum species are abundant among the brown algae occurring along the Indian shores and these are the chief sources for the extraction of alginic acids in the country (Umamaheswara Rao, 1970). More than 90 species of *Sargassum* have been reported from Indian shores (Srinivasan, 1966). From Visakhapatnam 4 species of *Sargassum* viz., *S.ilicifolium, S.polycystum, S.tenerrimum* and *S.vulgare* were reported (Umamaheswara Rao and Sreeramulu, 1970). The above four species have also been found in other localities along the coast of Visakhapatnam.

Sargassum species and other brown algae of the tropical shores are less investigated when compared with ecological, biological and biochemical aspects studied on the members of Laminariales and Fucales of temperate shores. *Sargassum muticum* species introduced from Japan has received much attention in recent years and many aspects relating to its distribution, growth and development, fruiting behaviour, dispersal and colonization have been studied in details by Fletcher and Fletcher (1975); Norton (1977a,b, 1980 and 1981); Fletcher (1980); and Chritchlez (1980). In other geographical areas also ecological and other investigations on the species of *Sargassum* were made in recent years by Yoshida (1960); Yoshida et al., (1963), Umezaki (1974), Tanuguchi and Yamada (1978) have worked on *Sargassum* species of Japan and De Wreede (1976) and Prince and O`Neal (1979) on *Sargassums* of Hawaii and America respectively.

In view of the importance of brown algae as a source of algin and as food, fodder and fertilizer, special efforts were made in India since 1950 to study the chemical composition and algin content of brown weeds by many workers. Later on,

studies were made on the seasonal changes on the extraction of alginic acid contents and on the life cycles of different species of *Sargassum* (Umamaheswara Rao, 1969; Chauhan and Krishnamurthy, 1971; Raju and Venugopal, 1971; Umamaheswara Rao and Kaliaperumal, 1976) growing along the Gujarat, Goa and Mandapam shores. At Visakhapatnam some preliminary observation were made on the seasonal changes in the abundance of brown algae in a general ecological study of the intertidal algae (Umamaheswara Rao and Sreeramulu, 1964; Umamaheswara Rao, 1990). . Several authors studied the seasonal growth, oospore shedding and other aspects on this brown alga in different geographical regions of the world (Chauhan and Krishna Murthy, 1967; 1971; Prince, 1980; Dawes, 1987; Umamaheswara Rao 1990; Ramalakshmi and Chauhan, 1992; Subba Rangiah, 1992; Appa Rao, 1998). Studies on sporulation play a vital role in the field of mariculture to generate the algal populations in the natural habitats. Several authors studied the spore shedding from *Sargassum* species in Indian waters (Chauhan and Krishnamurthy, 1971; Umamaheswara Rao and Kaliaperumal, 1976; Umamaheswara Rao, 1990; Appa Rao, 1998). In the present investigation studies were made on the oospore shedding from *Sargassum ilicifolium* in different environmental parameters at in two localities viz. Gangavaram and Pudimadaka along the Visakhapatnam coast was made for a period of two and half years from December 1995 to May 1998, is presented in this paper.

II. MATERIAL AND METHODS

Visakhapatnam is situated on the east coast of India between the latitude 17˚ 40’ 30’’ and 17˚ 45’ N longitudes 83˚ 16’ 25” and 83˚ 21’ 30”E. The coastline is sandy with outcrops of rocky boulders in different regions. Materials for this study were collected during the spring tide periods from Gangavaran and Pudimadaka regions where large accessible boulders occur with dense growth of algae. *Sargassum ilicifolium* J.Agardh was collected for carrying out the laboratory experiments during the years December, 1995 to May, 1998. Experiments were conducted on the effect of environmental factors on spore shedding and diurnal periodicity of oospore shedding from this marine alga. In the experiments conducted to study the exposure to air, the fronds were blotted to remove the water on the surface of the fronds and exposed to air in the laboratory and also in the open air during the day time. At the time of conducting these experiments the temperature in the laboratory was 28± 2°C and the relative humidity varied from 65 to 85%. In the open air where these experiments were conducted, the temperature was 32±2 C and relative humidity ranged from 52 to 76%. At 5 minute intervals the materials thus exposed to air were transferred to Petri-dishes filled with seawater and the spore output was estimated after 24 hours as mentioned in the earlier works (Subba Rangaiah, 1983). Seawater collected from the inshore area was adjusted to 80‰ salinity by exposing to sun light to make up the stock solution. Lower grades were prepared from this stock solution by the addition of requisite quantity of distilled water. Spore output was estimated at 0‰, 10‰,20‰ 30 ‰ 40 ‰ 50 ‰ 60‰, 70‰ and 80 ‰ salinities, maintaining the Petri-dishes at room temperature 28±2 C under 8 hours day length with 9 µ E m^{-2} s^{-1} day light fluorescent illumination. Effect of light intensity on oospore output were investigated at room temperature using light intensities of 0 (dark), 9 µ E m^{-2} s^{-1},18 µ E m^{-2} s^{-1}, 36 µ E m^{-2} s^{-1}, 54 µ E m^{-2} s^{-1}, 72 µ E m^{-2} s^{-1},90 µ E m^{-2} s^{-1}. To study the effect of photoperiod on the oospores shedding, experimental sets were subjected to 0:24, 4:20, 8:16, 12:12, 16:8, 20:4, 24:0(L: D cycles) in separate light and dark chambers performed in all light intensities ranging from 9 to 90 µ E m^{-2} s^{-1}. Based on the changes observed in the oospores output per day, experiments on diurnal periodicity were conducted selecting certain periods of exposure to air (0,15,30,45,60 minutes), salinities (10,20,30,40,50,60, 70, 80 ‰), light intensities (0,9,18,36,54, 72, 90 µ E m^{-2} s^{-1}), temperature (10,15,20,25,30,35,40,45°c). In all above experiments, the data collected were expressed as oospores per receptacles/day, to observe the quantity of oospores liberation under diverse environmental conditions.

III. RESULTS

Data collected on the influence of environmental factors such as exposure to air (desiccation), salinity, photon flux density, temperature and photoperiod on oospores shedding and diurnal periodicity were presented in the Fig. 1,2, 3,4,5,6,7 and 8 respectively.

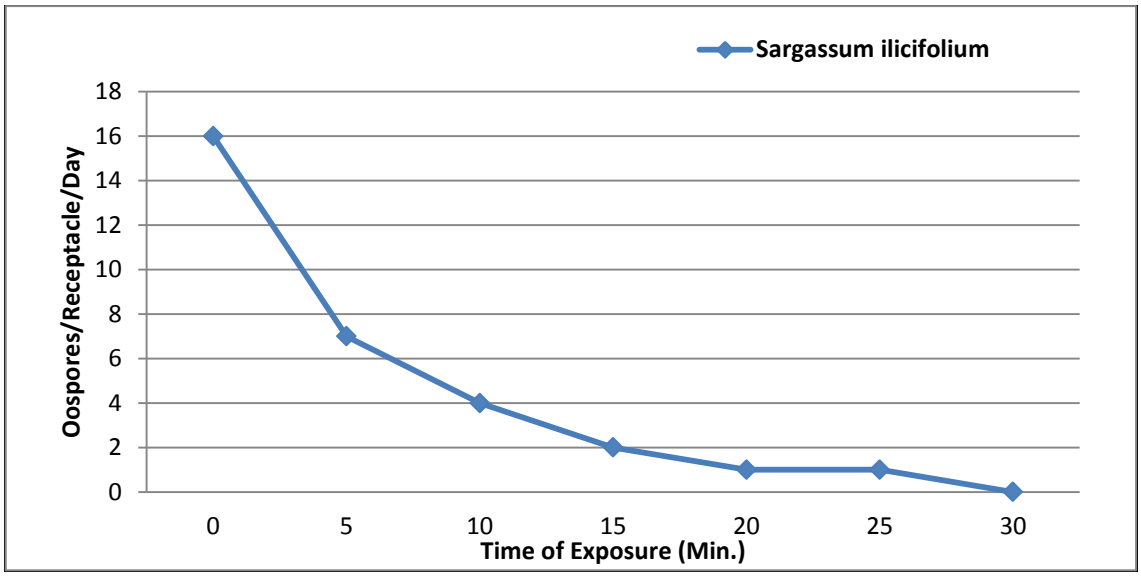
Factors Influencing Spore Shedding: Exposure to Air (Desiccation)

Changes observed in the oospore output of *Sargassum ilicifolium* in control (O minute exposure) and at different periods of exposure to air at room temperature in the laboratory and in the sunlight are shown in Fig 1A and 1B. In experiments conducted in shade i.e. in the laboratory, oospore shedding was seen up to 210 minutes exposure (Fig. 1B). Maximum

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spore output was observed in control where receptacles were submerged for 24 h duration and the number of oospores liberated decreased with increase in the duration of exposure of receptacles to air at laboratory temperature. The output of oospores was very low from the receptacles exposed to 120, 150,180 and 210 minutes respectively. Changes in oospore output were more marked when receptacles were exposed to sun light even for short periods of 5,10,15,20 and 25 minutes due to high temperature and low humidity. There was a sudden fall in oospore liberation from 0-5 minute's exposure. The shedding of oospores in *Sargassum illicifolium* after30 minutes was inhibited in the fronds exposed outside the laboratory (Fig.1A).

A: At Open Air Temperature 32± 2 ℃



B: At Room Temperature 28± 2 ℃

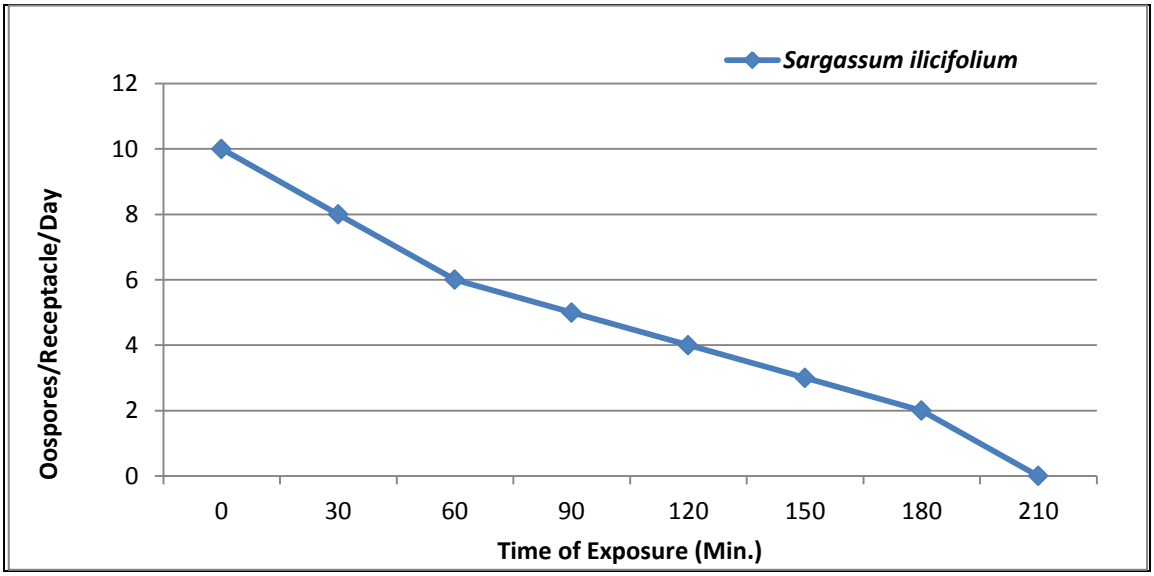


Fig. 1: Effect of Exposure to Air on the Oospores Shedding Of S.Ilicifolium

Salinity

Effect of salinity on oospore output of *Sargassum ilicifolium* was presented in Fig. 2. Oospore output varied markedly in different salinities of seawater tested and there was no liberation at 0 ‰ and 70 ‰ salinities. The oospore liberation was observed from 10 to 60 ‰ with minimum number of oospores at 10 and 60 ‰ salinities. Peak output of oospores was found at 30 ‰. But considerable number of oospores was also seen liberating from the receptacles at 20 ‰ and 40 ‰ salinities (Fig.2).

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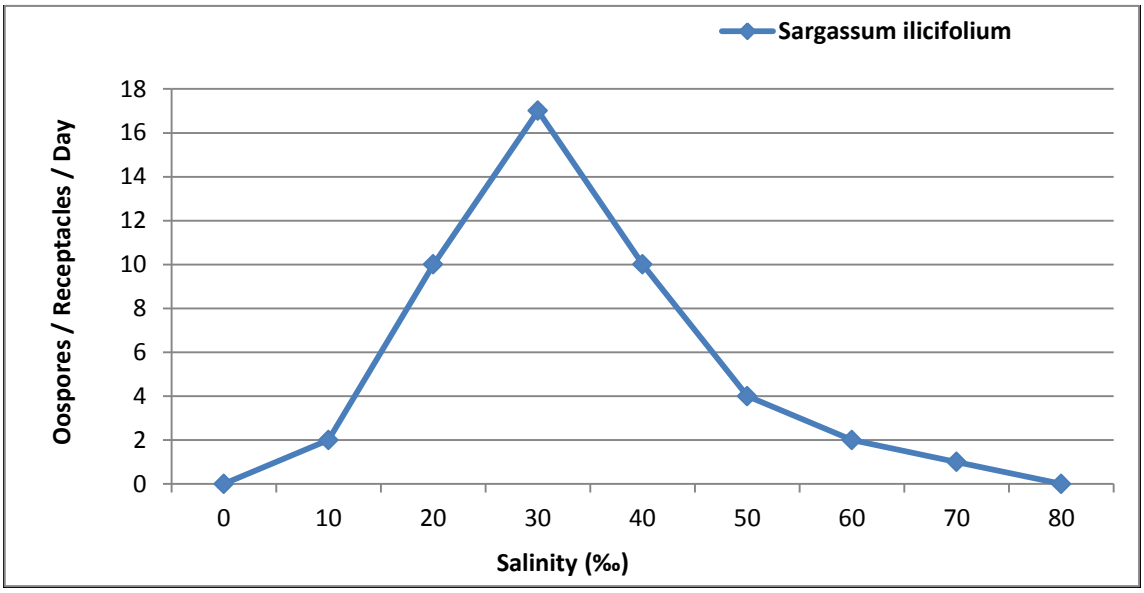


Fig. 2: Effect of Salinity on the Oospores Shedding Of S.Ilicifolium

Light Intensity (Photon Flux Density)

The quantity of oospores liberated from the receptacles of *Sargassum ilicifolium* exposed to dark to seven different light intensities ranging from 0 µ E m^{-2} s^{-2} to 90 µ E m^{-2} s^{-1} are presented in Fig. 3. Oospore output was varied in different photon flux densities raging from 0 µ E m^{-2} s^{-1} to 90 µ E m^{-2} s^{-1}. Peak shedding of oospores was found at 9 µ E m^{-2} s^{-} and considerable number at 18 µ E m^{-2} s^{-1} flux intensity and from there onwards the quantity of oospores liberated decreased gradually. Very low output of oospores was observed at 72 µ E m^{-2} s^{-1} and oospores output was totally inhibited at to 90 µ E m^{-2} s^{-1}.

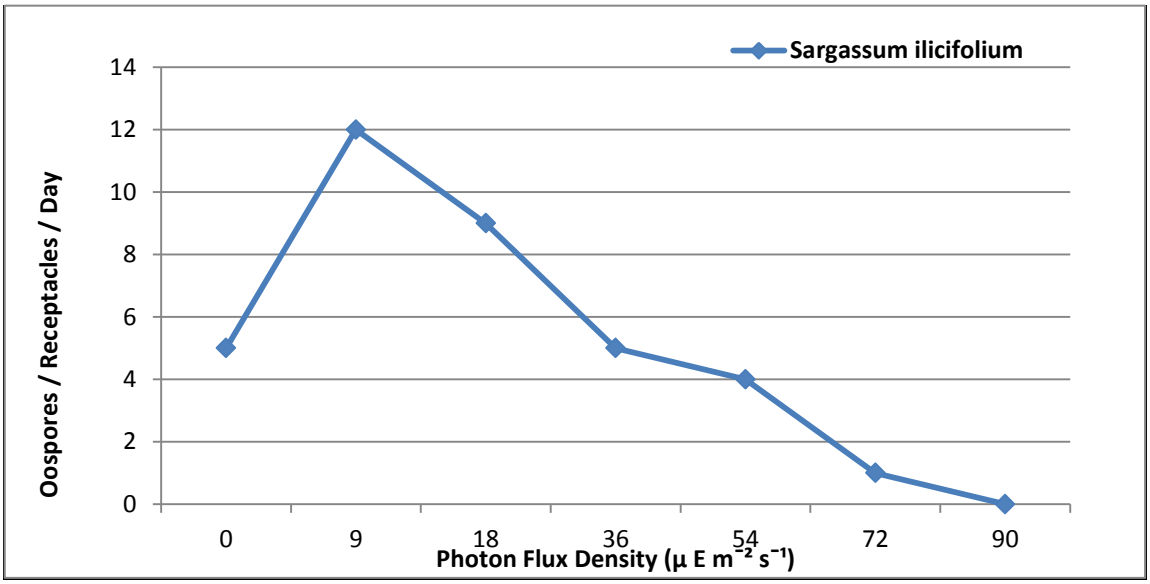


Fig. 3: Effect of Different Photon Flux Densities on the Oospores Shedding Of S.Ilicifolium

Temperature

Data collected on oospores output from the receptacles of S. ilicifolium exposed to different temperatures are presented in Fig. 4. Oospore shedding was seen from the receptacles, from 10°C onwards. The oospores liberation was very low at 10, 15 and 35°c and there was no shedding of oospores at 40 °c. Maximum number of oospores was seen liberating at 25°C. Considerable of oospores liberation was also observed at 20 and 30°C and the shedding was more at 20°C than at 30°C in *Sargassum ilicifolium*.

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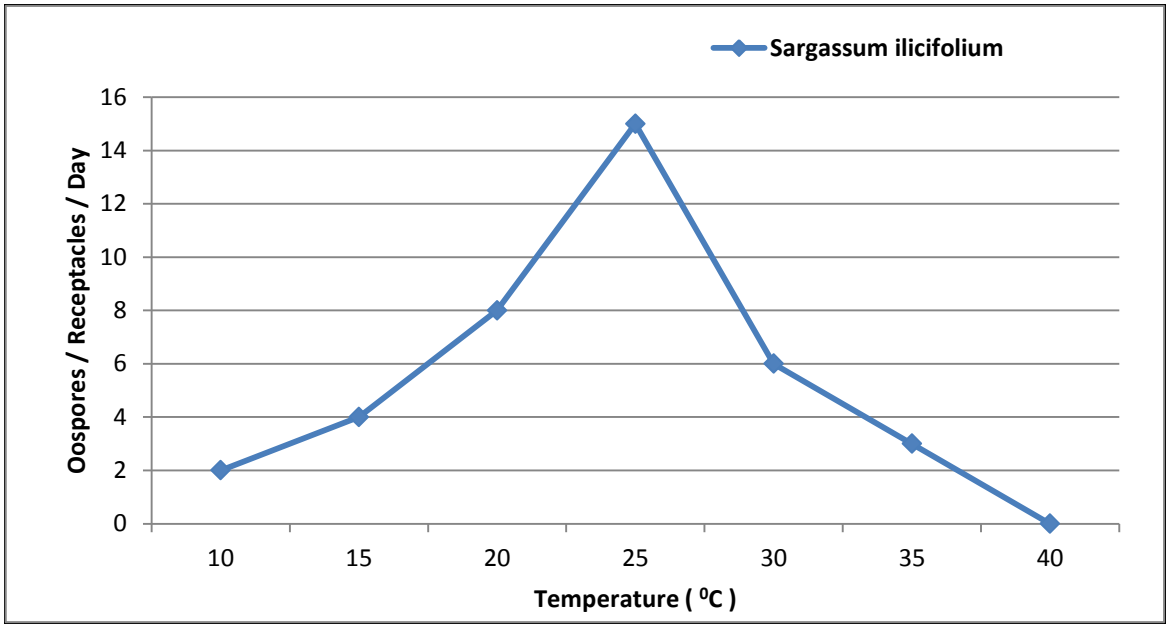


Fig. 4: Effect of Different Temperatures on the Oospores Shedding Of S.Ilicifolium

Photoperiod

The effects of light and dark regimes on oospores shedding are presented in fig. 5. These photoperiod experiments on Sargassum ilicifolium was conducted at 9, 18, 54 and 72 µ E m^{-2} s^{-1}. The above photon flux densities were selected depending upon the tolerance limits under continuous light, observed in the oospore output experiments at different photon flux densities. Peak output of oospores varied with the duration of photon flux densities received by the plants subjected to different L: D regimes. In Sargassum ilicifolium at a low photon flux density of 9 µ E m^{-2} s^{-1}, oospores output increased from 0 : 24 (L:D cycle) with maximum output at 12 : 12 (L:D cycle). Photoperiods more than 12 hours decreased oospore output. At 18, 54 µ E m^{-2} s^{-1}, peak liberation was observed at 12: 12(L: D cycle) in Sargassum ilicifolium. Oospores output decreased with further increase in the photoperiod at this photon flux densities. Maximum number of oospores shedding at 54 µ E m^{-2} s^{-1} was observed in 4: 20 (L: D cycle) and 8: 16 (L: D cycle). Whereas at 72 µ E m^{-2} s^{-1} the maximum oospores shedding were seen at 0: 24 (L: D cycle) and 4: 20 (L: D cycle), the oospores shedding was decreasing. Photoperiod altered the peak shedding of oospores output depending upon the L: D cycles and light energy.

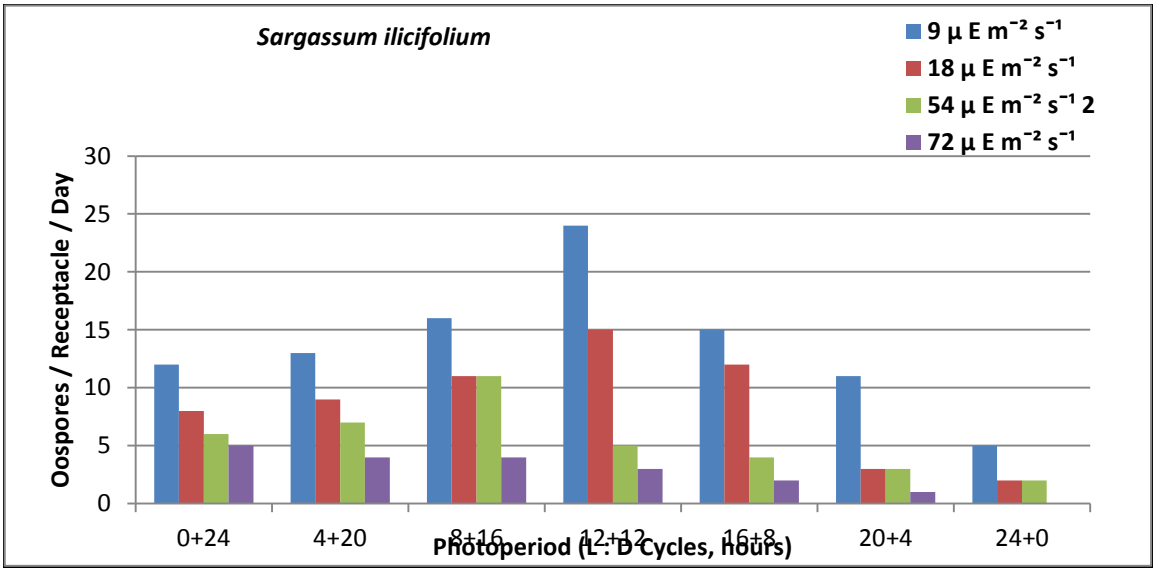


Fig. 5: Effect of Different Photoperiods on the Oospores Shedding Of S.Ilicifolium at Different Photon Flux Densities.

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Factors Influencing Diurnal Periodicity

Effects of desiccation, salinity, photon flux density and temperature observed on the diurnal periodicity in the liberation of oospores are presented here.

Exposure to Air (Desiccation)

Data obtained on the diurnal periodicity by exposing the receptacles of *Sargassum ilicifolium* from control (submerged condition) to 240 minutes. Peak shedding of oospores was observed in the receptacles of 0 minute exposure between 0200 h and 0600 h without any change in the normal shedding period (Fig.6). Whereas the receptacles exposed to air under shade (room temperature) from 60 to 240 minutes, peak shedding of oospores was delayed. For instance at 60 minutes exposure, 4h delay was observed in the peak shedding of oospores (shifted from 0200-0600 h to 0600h-1000h). At 120 minutes exposure, peak output of oospores was observed between 1000 and 1400 h with further increase in the duration of exposure (240 minutes) peak output was not observed up to 1800h. In fact in receptacles exposed for 240 minutes oospore output was not seen up to 1400 h (Fig.6).

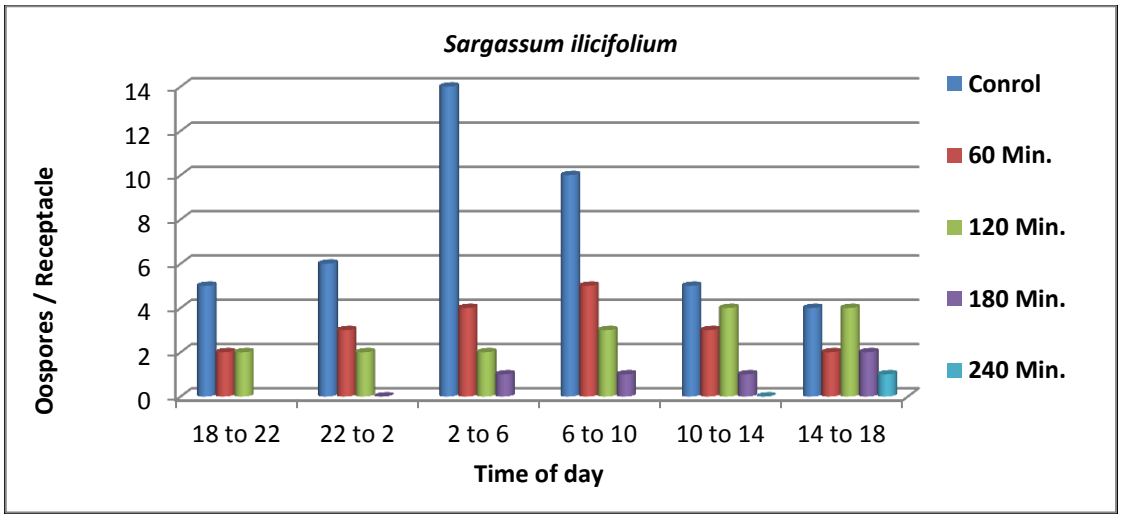


Fig. 6: Effect of exposure to air on diurnal periodicity in the liberation of oospores of S.ilicifolium

Salinity

Influence of five different salinities on the diurnal periodicity of oospore release is depicted in Fig.7. The peak output of oospores was observed in *Sargassum ilicifolium* between 0200 and 0600 h in salinities ranging from 20- 40‰ salinity without any shift in the time of peak shedding of oospores in a day. But at10 and 50‰, the diurnal variations are not prominent since very less number of oospores was liberated from the receptacles.

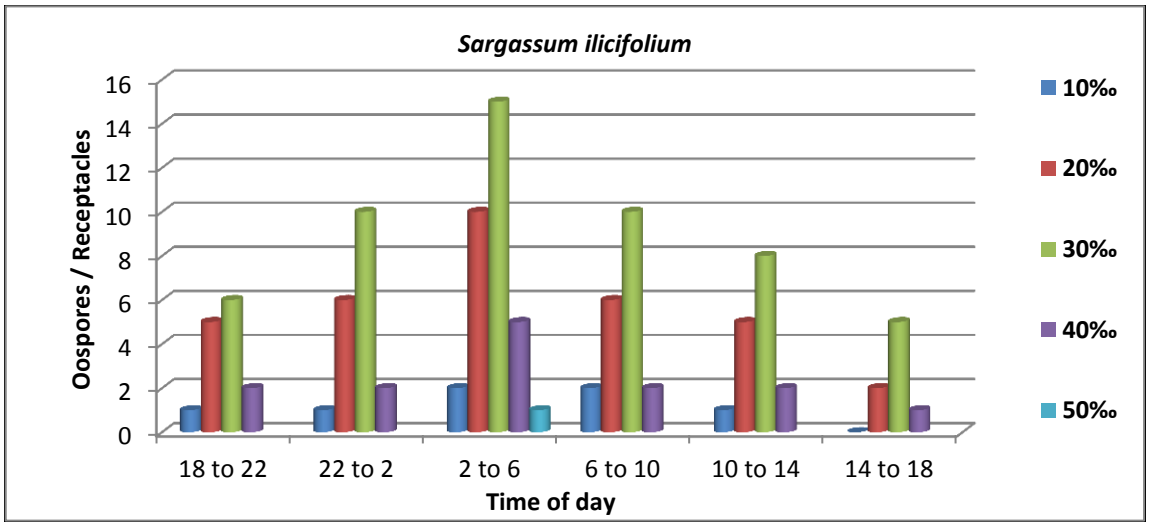


Fig. 7: Effect of Salinity on Diurnal Periodicity in the Liberation of Oospores of S.Ilicifolium

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Light Intensity

Diurnal periodicity in the liberation of oospores from the receptacles kept in dark and in four different photon flux intensities viz. 0 µ E m^{-2} s^{-1}, 9 µ E m^{-2} s^{-1}, 36 µ E m^{-2} s^{-1} and 72 µ E m^{-2} s^{-1} are presented in the Fig. 8. The peak shedding of oospores was observed between 0200h to 0600h in dark as well as at photon flux densities of 9,36, 72µ E m^{-2} s^{-1}, without any change in the pattern of diurnal curves. Prominent peak with more number of oospores were obtained at 9 µ E $m^{-2}s^{-1}$ and from 9 µ E $m^{-2}s^{-1}$ onwards the number of oospores shed, decreased gradually. Though the number of oospores liberated in dark, and at photon flux densities of 36 and72 µ E $m^{-2}s^{-1}$ conspicuous peak of shedding rhythms were observed between 0200 and 0600h

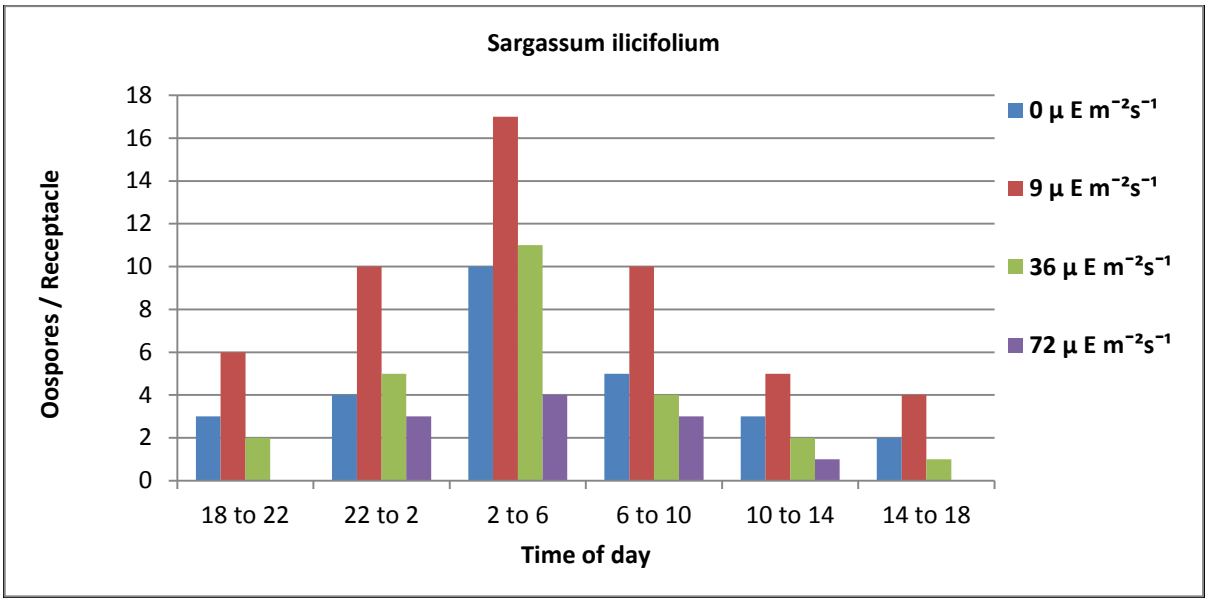


Fig. 8: Effect of Different Photon Flux Densities on Diurnal Periodicity in the Liberation of Oospores of S.Ilicifolium

IV. DISCUSSION AND CONCLUSION

In the present study oospores shedding abilities of *S.ilicifolium was* influenced by some environmental factors such as exposure to air, salinity, Photon flux density, temperature, and photoperiod. Withstanding ability of different marine algae to these environmental parameters depend on the vertical distribution of algae on rocky surfaces. The eco-physiological investigations of spore shedding on Indian marine algae was studied by several authors (Subba Rangaiah, 1983; 1984; 1985a; 1985b; 1986) and studies on spore shedding of brown algae was fragmentary (Umamaheswara Rao and Sanjeeva Reddy, 1982; Narasimha Rao.1989; Narasimha Rao and Subba Rangaiah, 1991; Appa Rao.1995; 1998). In the present study oospore shedding in *S.ilicifolium* was observed only for 30 min exposure outside the lab and 210 min inside the lab. These observations on *S.ilicifolium* agree with the findings on S. vulgare (Appa Rao, 1998) and also depend on the distribution of this alga in the intertidal habitat. Salinity of the seawater influences oospore shedding in *S.ilicifolium* the optimum salinity range observed for the maximum shedding in *S.ilicifolium* was 30 ‰. Several studies reveals the effect of salinity on spore shedding and observed different optimum ranges (Subba Rangaiah et al, 1975; Umamaheswara Rao and Sanjeeva Reddy, 1882 ; Subba Rangaiah, 1983;1985b; 1986;Narasimha Rao.1989; Appa Rao,1995; 1998). Oospore liberation in *S.ilicifolium* occurred in the light intensities ranging from 0 to 90 µ E m^{-2} s^{-1} with peak shedding at 9 µ E m^{-2} s^{-1}. Similar trend was reported by Narasimha Rao and Subba Rangaiah, 1991; Appa Rao, 1995 and Subba Rangaiah and AppaRao, 1998). In the present study peak discharge of oospores in Sargassum ilicifolium was found at 25^0C, agreeing with the optimum range reported for Dictyota (Umamaheswara Rao and Sanjeeva Reddy, 1982); and the members of red algae studied by Umamaheswara Rao and Kaliaperumal, (1983); and Umamaheswara Rao and Subbarangaiah, (1986). Matsui (1969) observed that the time of peak liberation of spores in the fronds of *Gloiopeltis* species exposed to air for 2 to 6 h was accelerated by 10 h. In the present study in *S.ilicifolium* showed delay in the peak shedding of oospores for about 4h in the receptacles exposed for 60 minutes and 8h delay in the receptacles exposed for 120 minutes. In the previous studies made by Umamaheswara Rao and Kaliaperumal (1987) on Gelidium pusillum, where 4h delay in spore shedding was observed in fronds exposed for 45 minutes. Variations in the salinity did not affect diurnal

periodicity pattern in the members of Dictyotales and species of Sargasssum (Umamaheswara Rao and Sanjeeva Reddy, 1982; Appa Rao, 1998). The observations of the present investigation agree with the above findings. When the receptacles of *S.ilicifolium* exposed up to 9, 36 and 72 μ E m^{-2} s^{-1}, there was no change in the peak period of shedding of oospores (Fig.6). In this respect the present study agrees with the results of Umamaheswara Rao and Sanjeeva Reddy (1982), Sudhakar (1992), Sudhakar and Subbarangaiah (1993, 1997a) on Ceramiales, Appa Rao (1998). It seems that photon flux density did not have any effect on the diurnal periodicity of oospores shedding in Sargassum ilicifolium. In the present study, there was no shifting of peak liberation of oospores at different temperatures i.e., at 15, 20, 25 and 30^0C.It is interesting to note that the quantity of oospores liberated in *S.ilicifolium* of the present study is almost less than half when compared to the studies made by Subba Rangaiah (1983 a). This change may be due to increase in the temperature (2-3ºC) in the nature, and indiscriminate discharge of industrial effluents in to the sea. If this process continues, we do hope that in future there will be a drastic change in the seaweeds of Visakhapatnam towards decrease in the vegetation as well as in spore shedding capacities. So, we request the Government and NGO s to take necessary steps to conserve the seaweeds of Visakhapatnam by taking proper steps. Present study on different factors, it can be concluded that the submerged condition of fronds, photon flux density of 9 μ E m^{-2} s^{-1}, salinities around normal sea water (30 ‰) and temperatures around 25^0C are favourable for maximum oospores shedding of Sargassum ilicifolium. These experimental findings closely agree with the environmental conditions existing in the intertidal habitats at Gangavaram and Pudimadaka of the Visakhapatnam coast.

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