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Research Article

Effect of environmental factors on oospores shedding and diurnal periodicity in *Sargassum vulgare* C.Agardh. along the Visakhapatnam coastline, east coast of India

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Abstract: *Sargassum vulgare* C.Ag. was observed in Jodugullapalem of Visakhapatnam coast and 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, 9μE$m^{-2}s^{-1}$ 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.vulgare* was found 2:00-6:00 hours.
Keywords: *Sargassum vulgare*, Oospores shedding, Environmental factors, Photoperiod, Diurnal periodicity, Jodugullapalem.

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[1] . More than 90 species of *Sargassum* have been reported from Indian shores [2]. From Visakhapatnam 4 species of *Sargassum* viz., *S.ilicifolium, S.polycystum, S.tenerrimum* and *S.vulgare* were reported[3]. 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 [4-10]. In other geographical areas also ecological and other investigations on the species of *Sargassum* were made in recent years on *Sargassum* species of Japan [11-14] and on *Sargassums* of Hawaii and America respectively[15-16].

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* growing along the Gujarat, Goa and Mandapam shores [17-19]. 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[20, 21]. Several authors studied the seasonal growth, oospores shedding and other aspects on this brown alga in different geographical regions of the world [21-28]. 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 [22,21, 28].

In the present investigation studies were made on the oospores shedding from *Sargassum vulgare* in different environmental parameters at in Jodugullapalem 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.

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 Jodugullapalem region where large accessible boulders occur with dense growth of algae. *Sargassum vulgare* C.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 oospores 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^{o}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 [29]. 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 oospores 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^{o}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.

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, 3,4,5,6,7,8 and 9 respectively.

Factors Influencing Spore Shedding: Exposure to Air (Desiccation)

Changes observed in the oospores output of *Sargassum vulgare* 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, oospores shedding was seen up to210 minutes exposure (Fig. 1B). Maximum 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 oospores 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 oospores liberation from 0-5 minute’s exposure. The shedding of oospores in *Sargassum vulgare* after30 minutes was inhibited in the fronds exposed outside the laboratory (Fig.1A).

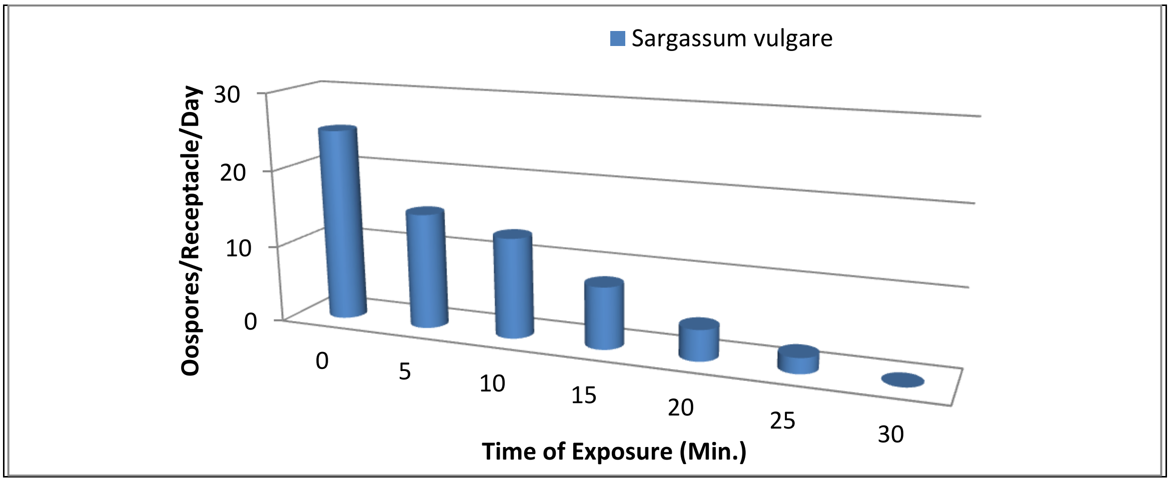

Fig. 1(A): Effect of Exposure to Air on the Oospores Shedding Of S.vulgare at Open Air Temperature 32± 2^{0}C

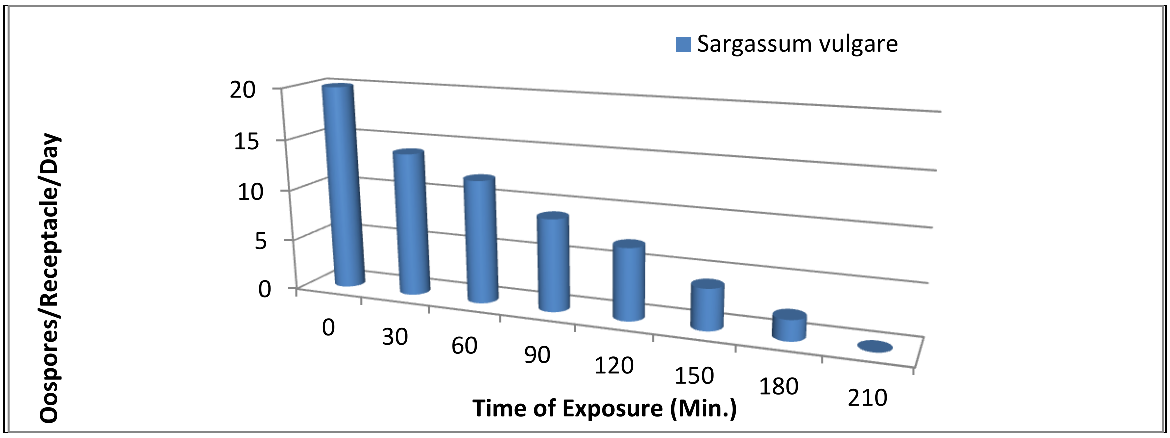

Fig. 1(B): Effect of Exposure to Air on the Oospores Shedding Of *S.vulgare* at Room Temperature 28± 2^{0}C

Salinity

Effect of salinity on oospores output of *Sargassum vulgare* was presented in Fig. 2. Oospores output varied markedly in different salinities of seawater tested and there was no liberation at 0 ‰ and 70 ‰ salinities. The oospores 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)

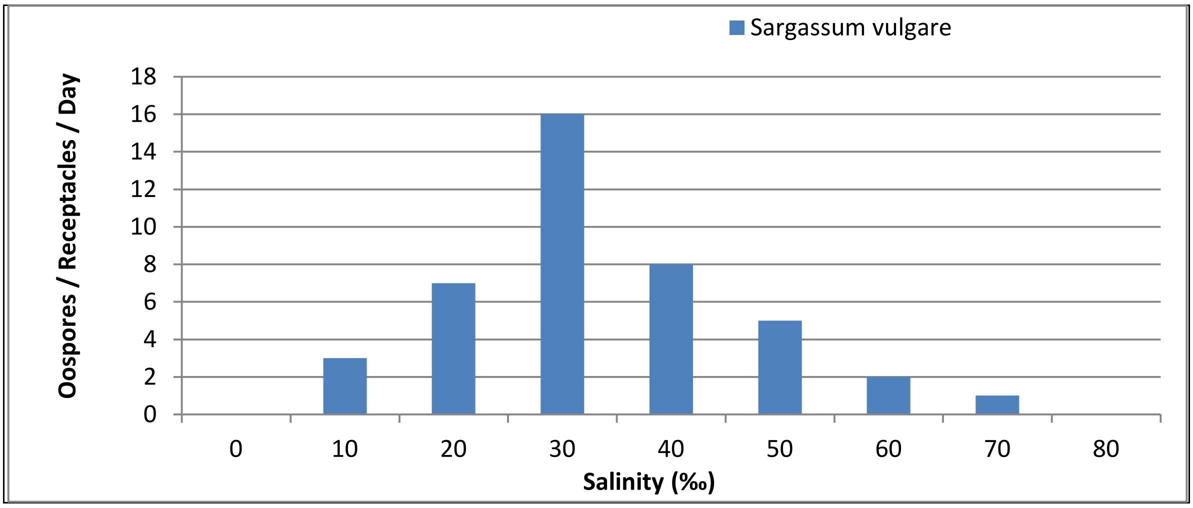

Fig.2: Effect of Salinity on the Oospores Shedding Of *S.vulgare*

Light Intensity (Photon Flux Density)

The quantity of oospores liberated from the receptacles of *Sargassum vulgare* 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. Oospores 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}.

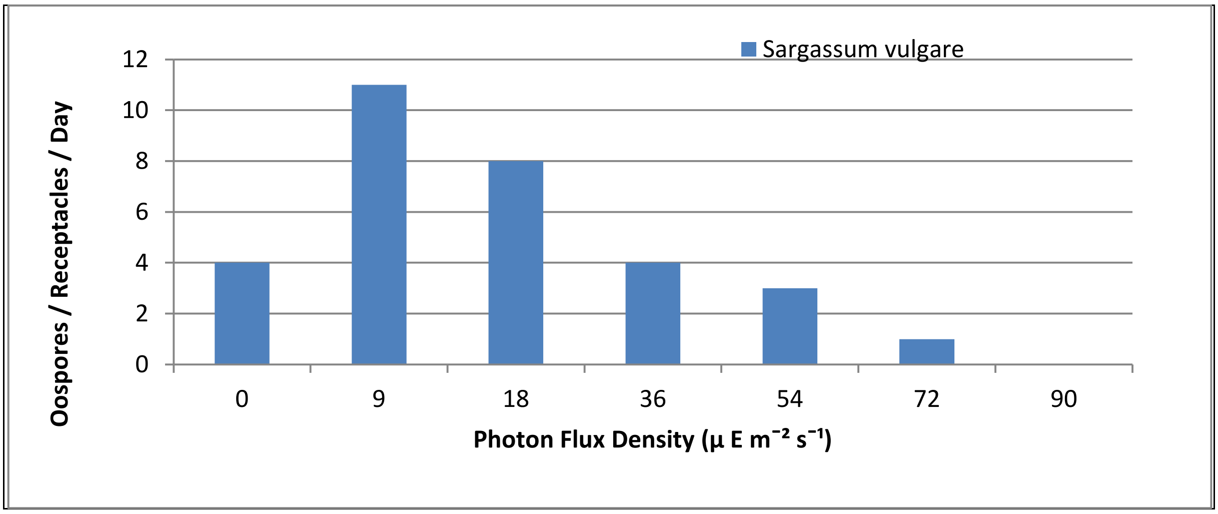

Fig. 3: Effect of Different Photon Flux Densities on the Oospores Shedding Of *S.vulgare*

Temperature

Data collected on oospores output from the receptacles of S. vulgare 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 vulgare*.

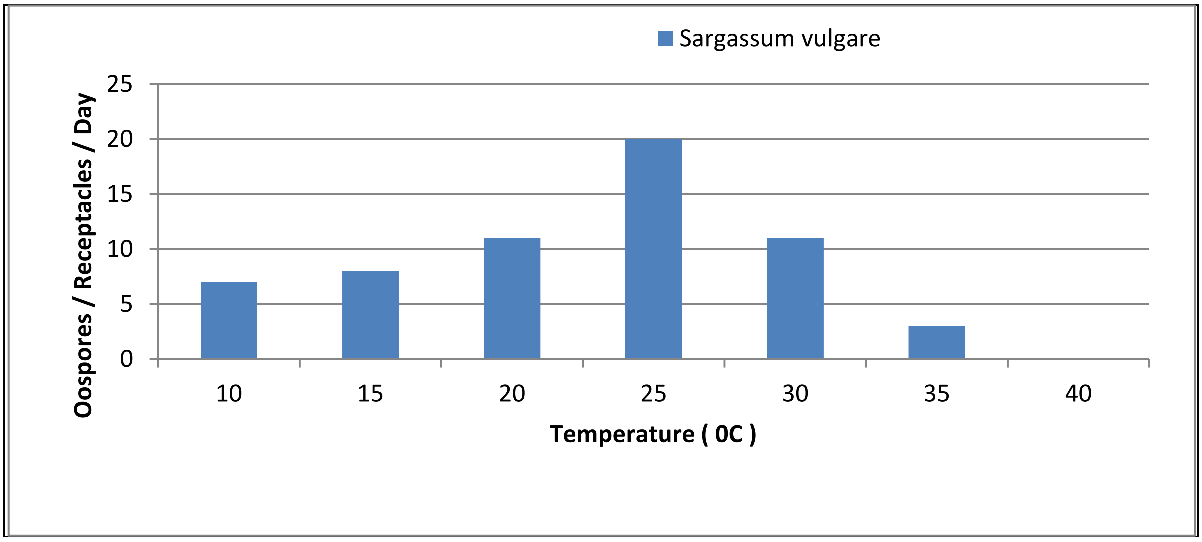

Fig. 4: Effect of Different Temperatures on the Oospores Shedding Of *S.vulgare*

Photoperiod

The effects of light and dark regimes on oospores shedding are presented in fig. 5. These photoperiod experiments on *Sargassum vulgare* 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 oospores 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 vulgare 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 oospores output. At 18µ E m^{-2} s^{-1}, peak liberation was observed at 08: 16(L: D cycle), 54 µ E m^{-2} s^{-1}, peak liberation was observed at 04: 20(L: D cycle) in Sargassum vulgare. Oospores output decreased with further increase in the photoperiod at this photon flux densities, Whereas at 72 µ E m^{-2} s^{-1} the maximum oospores shedding were seen at 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.

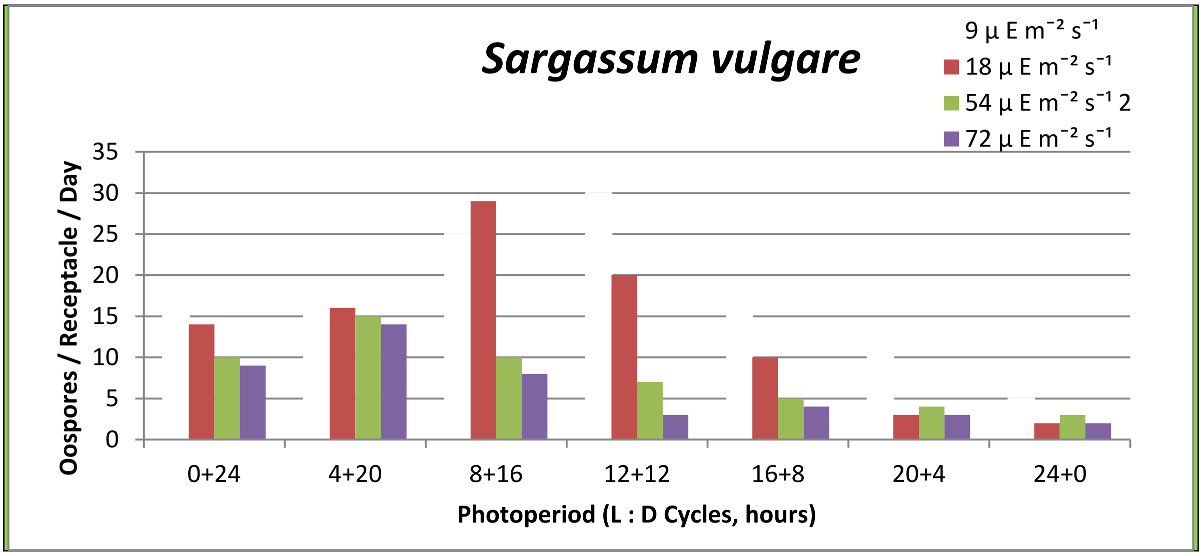

Fig. 5: Effect of Different Photoperiods on the Oospores Shedding Of *S.vulgare* at Different Photon Flux Densities.

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 vulgare* 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 oospores output was not seen up to 1400 h (Fig.6).

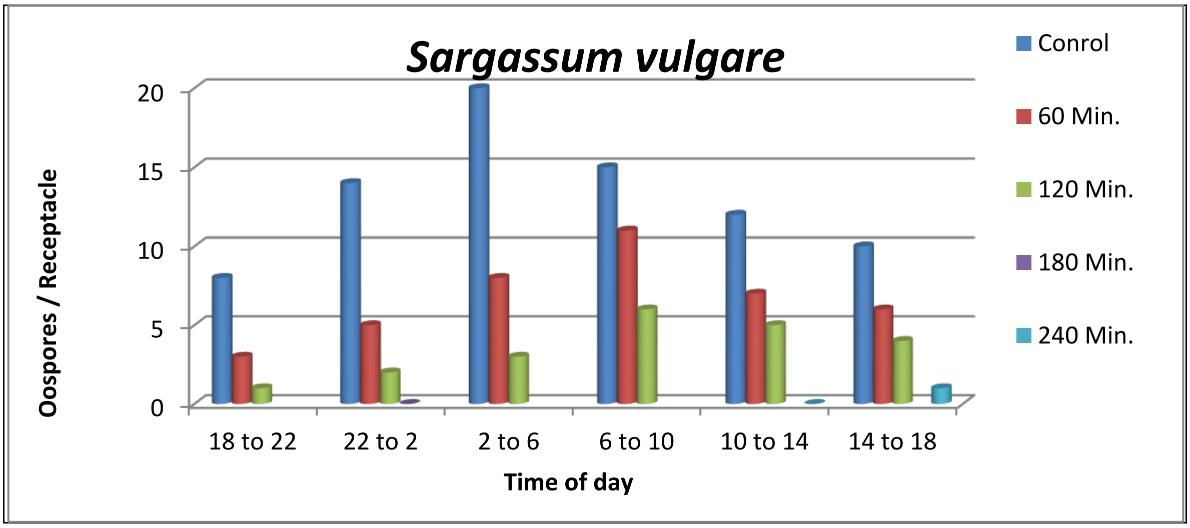

Fig. 6. Effect of exposure to air on diurnal periodicity in the liberation of oospores of *S.vulgare*

Salinity

Influence of five different salinities on the diurnal periodicity of oospores release is depicted in Fig.7. The peak output of oospores was observed in *Sargassum vulgare* 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 and50‰, the diurnal variations are not prominent since very less number of oospores was liberated from the receptacles.

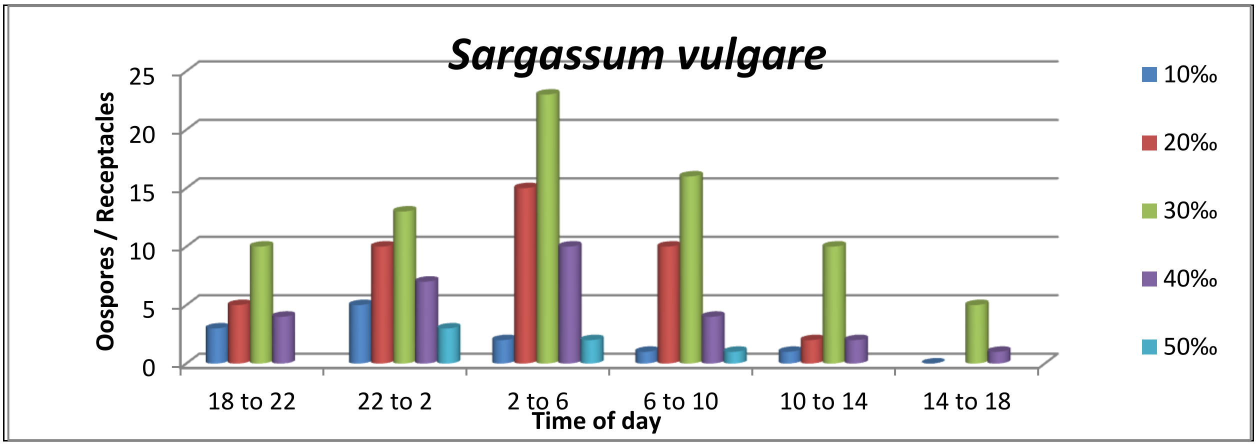

Fig. 7. Effect of Salinity on Diurnal Periodicity in the Liberation Of Oospores Of *S.vulgare*

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 and72µ E $m^{-2}s^{-1}$ conspicuous peak of shedding rhythms were observed between 0200 and 0600h

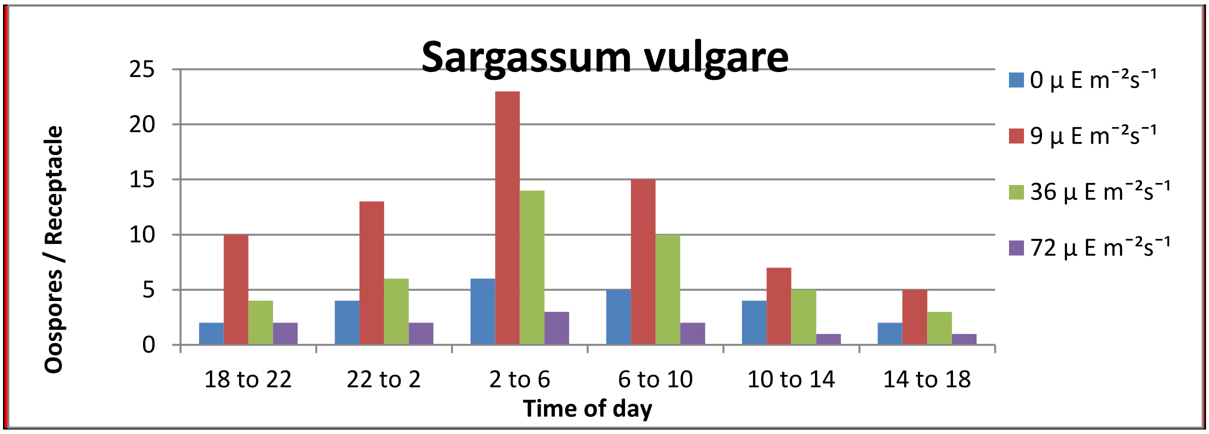

Fig. 8. Effect of Different Photon Flux Densities on Diurnal Periodicity in the Liberation of Oospores of *S.vulgare*

Temperature

Peak output of oospores was observed between 0200and 0600 in all the four temperatures (15, 20,25and 30^{0}C) tested. The maximum output of oospores liberation was seen at 25^{0}C and less number at 15^{0}C.

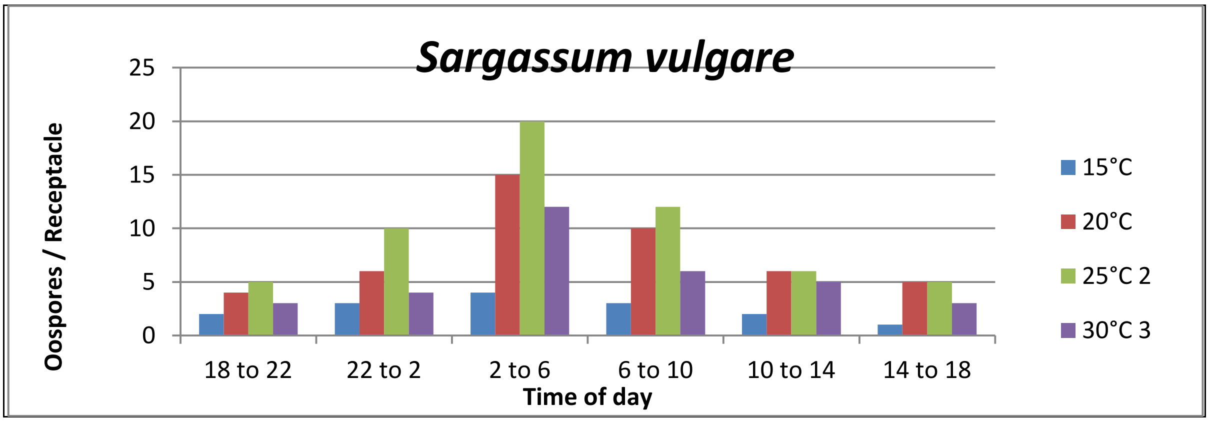

Fig-9: Effect of Different temperatures on Diurnal Periodicity in the Liberation of Oospores of *S.vulgare*

DISCUSSION

In the present study oospores shedding abilities of *S.vulgare 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[29-33] and studies on spore shedding of brown algae was fragmentary [34-36, 28].

In the present study oospores shedding in *S.vulgare* was observed only for 30 min exposure outside the lab and 210 min inside the lab. These observations on *S.vulgare* agree with the findings on S. ilicifolium [28] and also depend on the distribution of this alga in the intertidal habitat. Salinity of the seawater influences oospores shedding in *S.vulgare the* optimum salinity range observed for the maximum shedding in *S.vulgare* was 30 ‰. Several studies reveals the effect of salinity on spore shedding and observed different optimum ranges [28, 29-31, 35-36]. Oospores liberation in *S.vulgare* 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 [36,27,28].

In the present study peak discharge of oospores in Sargassum vulgare was found at 25^0C, agreeing with the optimum range reported for Dictyota [34]. and the members of red algae studied [37-38]. It was 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[39]. In the present study in *S.vulgare* 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 [40] 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 [28, 34]. The observations of the present investigation agree with the above findings. When the receptacles of *S.vulgare* 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 previous studies [34, 28, 41-43]. It seems that photon flux density did not have any effect on the diurnal periodicity of oospores shedding in Sargassum vulgare. 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. 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 vulgare*.

CONCLUSION

These experimental findings closely agree with the environmental conditions existing in the intertidal habitat at Jodugullapalem of the Visakhapatnam coast. It is interesting to note that the quantity of oospores liberated in *S.vulgare* 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 (2-3°C) 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 coast towards decrease in the vegetation as well as in spore shedding capacities.

REFERENCES

1. Umamheswara Rao M; The economic seaweeds of India, Bull. Cent. Mar. Fish. Res. Instt. 1970; 20: 1-68
2. Srinivasan KS; Conspectus of *Sargassum* species from Indian territorial waters. Phykos, 1966; 5: 127-159.
3. Umamaheswara Rao M, Sreeramulu T; An annotated list of the marine algae of Visakhapatnam (India). Bot. J.Lin, 1970; 63: 23-45.
4. Fletcher RL, Fletcher SM; Studies on the recently introduced brown alga *Sargassum muticum* (yendo) Fensholt I. Ecology and Reproduction. Bot.Mar, 1975; 18: 149-156.
5. Norton TA; Ecological experiments with *Sargassum muticum*. J. Mar. Biol. Ass. U.K., 1977; 57: 33-43.
6. Norton TA; Growth and development of *Sargassum muticum* (Yendo) Fensholt. J. Exp. Mar. Biol. Ecol, 1977b; 26:41-53.
7. Norton TA; Sink, Swim or Stick of *Sargassum muticum* propagules. Br .Phycol. J, 1980; 15:197-198.
8. Norton TA; Gamete expulsion and release in *Sargassum muticum*. Bot. Mar, 1981; 24: 465-470.
9. Fletcher RL; Studies on the recently introduced brown alga *Sargassum muticum* (yendo) Fensholt III. Periodicity in gamete release and incubation of early germling stages. Botanica Mar, 1980; 23: 425-432.
10. Chritchley AT; The further spread of *Sargassum muticum.* Br. Phycol. J, 1980; 15: 194.
11. Yoshida T; On the growth rings found in the root of *Sargassum ringoldianum* Harvey (Fucales). Bull. Jap. Soc.Sci. Fisheries, 1960. 26(7): 673-678.
12. Yoshida T; *Sargassum* vegetation growing in the sea around Tsuyazaki, North Kyushu, Japan. Pacific Sci.,1963; 17(2): 135-144.

13. Umejaki I; Ecological studies of *Sargassum thunbergii* (Mertens) Kuntze in Maizuru Bay, Japan Sea. Bot. Mag. Tokyo, 1974; 87: 284-292.
14. Taniguchi K, Yamada Y; Ecological studies on *Sargassum patens* C.Agardh and *S.serratifolium* C.Agardh in the sublittoral zone at Lida Bay of Noto Peninsula in the Fish Res.Lab., 1978; 29: 239-253.
15. De Wreede R E; The phenology of three species of *Sargassum* (Sargassaceae, Phaeophyta) in Hawaii. Phycologia, 1976; 15: 175-183.
16. Prince JS, O'Neal SW; The ecology of Sargassum pteropleuron Grunow (Phaeophyceae/ Fucales) in the waters off South Florida I. Growth, reproduction and population sturucture. Phycologia, 1979; 18: 109 -114.
17. UmamaheswaraRao M; Seasonal variations in growth, alginic acid and mannital contents of *Sargassum wightii* and *Turbinaria conoides* from the Gulf of Mannar, India. 6th Int. Natl. Seaweed Symp, 1969; 579-584.
18. Raju PV, Venugopal R; Appearance and Growth of Sargassum plagiophyllum (Mert) C. Agardh on a fresh substratum. Bot. Mar, 1971; 14: 36-38.
19. Umamaheswara Rao M, Kaliaperumal N; some observations on the liberation and viability of oospores in *Sargassum wightii* (Greville) J.Agardh. Indian J. Fish. 1987; 24: 232-235.
20. Umamaheswara Rao M, Sreeramulu T; An ecological study of some intertidal algae of the Visakhapatnam coast. J.Ecol. 1964; 52: 595-616.
21. Umamaheswara Rao M; Autecological and Eco-physiological studies on marine algae of Visakhapatnam and Mandapam coast. Perceptives in phycology (M.O.P. Iyangar Centinary celebration volume) Ed. V.N.Raja Rao, 1990; 323-335.
22. Chauhan VD, Krishnamurthy V; Ecology and Seasonal succession of *Sargassum swartzii* (Turn) C.Ag. in Indian waters. Phykos; 10: 1-11.
23. Prince JS; The ecology of *Sargassum pteropleuron* Grunow in the waters off South Florida II. Phycologia, 1980; 19: 190-193.
24. Dawes CJ; Physiological ecology of two species of Sargassum on the west coast of Florida, Bull. Mar. Sci, 1987; 40(2):198-209.
25. Ramalakshmi Y, Chauhan VD; Ecological study of Sargassum swartzii (Turn) C.Ag. on the coast of port Okha, Gujarat. J. Env. Biol. 1992; 13(2): 135-144.
26. Subba Rangaiah G; A persistent endogenous circadian rhythm of liberation of eggs in Fucus serratus. British Phycological winter meeting, Birmingham, January, 1992; 6-9.
27. Appa Rao D; Studies of spore shedding in *Padina tetrastromatica* Hauck (Phaeophyceae) of the Visakhapatnam coast. M.Phil dissertation, Andhra University, Waltair (India), 1995.
28. Appa Rao D; Studies on the ecology of some species of Sargassum (Fucales, Phaeophyceae) along the Visakhapatnam coast (India). Ph.D.thesis, Andhra University, Waltair (India), 1998.
29. Subba Rangaiah G; Seasonal growth, reproduction and spore shedding in *Gracilaria corticata*. J. Ag. of the Visakhapatnam coast. Indian Natl.Sci. Acad. B.1983; 49(6): 711-718.
30. Subba Rangaiah G; Growth, reproduction and spore shedding in *Gracilaria textorii* (Sur.) J. Ag. of the Visakhapatnam coast. Phykos, 1984; 23: 246-253.
31. Subba Rangaiah G; Spore shedding in *Gracilariopsis sjoestedtii* (Kylin) Dawson (Rhodophyta, Gigartinales). Proc. All India symp.mar. Plants, their biology, chemistry, utilization (ed. Krishnamurthy, V. and Untawale, A.G.)Seaweed Research and Utiln. Assoc. India, 1985;59-64.
32. Subba Rangaiah G; Influence of temperature on diurnal periodicities of tetra spores of some members of Gigartinales (Rhodophyta) Seaweed Research Utiln, 1985; 8:23-27.
33. Subba Rangaiah G; Effects of environmental factors on the shedding of monospores from *Porphyra vietnamensis* Tanaka et. Ho of the Visakhapatnam coast. Phykos, 1986; 25: 29-35.
34. Umamheswara Rao M, Sanjeeva Reddy; Influence of desiccation, salinity and temperature on the liberation and germination of tetraspores of *Dictyota dichotoma*. Seaweed Res. Utiln, 1982; 6(1): 5-9.
35. Narasimha Rao GM; Effect of environmental factors on spore shedding from *Rosenvingea nhatrangensis* Dawson. Mahasagar, 1989; 22(3): 135-137.
36. Narasimha Rao GM, Subba Rangaiah G; Control of spore shedding from some marine algae of the Visakhapatnam coast, India. Br. Phycol. J, 1991; 26: 356-360.
37. Umamaheswara Rao M, Kaliaperumal N; Effects of environmental factors on the liberation of spores from some red algae of Visakhapatnam coast. J. Exp. Mar. Biol. Ecol, 1983; 70: 45-53.
38. Umamaheswara Rao M, Subba Rangaiah G; Effect of environmental factors on the shedding of tetra spores of some Gigarinales (Rhodophyta). Proc. Symp. Coastal Aquaculture, 1986; 4:1199-1205.
39. Matsui T; Studies on liberation and germination of spores in *Gloiopeltis tenax* (Turn) J.Ag. and *G.furcat*a post et. Rupr. J.Shimonseki Univ.Fish, 1969; 17: 185-231.
40. Umamaheswara Rao M, Kaliaperumal N; Effect of thermal stress on spore shedding in some red algae of Visakhapatnam coast. Indian J. Mar.Sci, 1987; 16: 201-202.
41. Sudhakar S; Ecological studies on some Ceramiales (Rhodophyceae) of the Visakhapatnam coast. Ph.D thesis, Andhra University, Waltair, India, 1992.
42. Sudhakar S, Subba Rangaiah G; Circadian periodicities in the shedding of spores in *Wrangelia argus* Mont. and Centroceras clavulatum Ag.

Mont. (Ceramiales, Rhodophyta) of the Visakhapatnam coast. National symposium on seashore ecosystem diversity in India with special reference to marine algae Madras, February 26-28th, 1993.

43. Sudhakar S, Subba Rangaiah G; Diurnal periodicity in the shedding spores in *Polysiphonia platycarpa* Borgesen (Rhodophyceae, Ceramiales) of the Visakhapatnam coast. National symposium on Recent trends in algal Research, March, 6-8th, Andhra University, Waltair, 1997.