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Spore discharge in the marine red and brown algae of the Coastal waters along the East Coast of India—A review

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INTRODUCTION

Marine algae widely used as food, fodder and fertilizer, in recent years sources for important bioactive compounds and bio-fuels. Further these are also harvested and commercially cultivated for the phycocolloids. Phycocolloids used in variety of industries such as Pharma, chemical and food sector units. Availability of raw material is one of the limiting factors for running industries. Mass outdoor cultivation of these marine algal forms would generate the required biomass for continuous running of the industries. Tetra spores and carpospores play a vital role in the aquaculture for generating these marine algal populations in a large scale. Studies in connection with the spore shedding will be useful for the production of the required algal populations in a commercial scale.

Spores are singled celled reproductive structures and are capable of develop into new organism. The term spore derived from the Greek word ‘spora’ means seed, spores are usually haploid structures and unicellular structures which develop into adult populations. Commercial cultivation of important marine algal forms will aid to cater the needs of the seaweed industries in India. Marine algae liberate various types of spores for maintaining their progeny in the natural habitats for ever. Several studies were undertaken in various parts of our country to find out the suitable season, suitable time for liberation of these important propogules. Besides environmental parameters such as temperature, light intensity, salinity, desiccation and thermal stress play an important role on the shedding of the spores. In the present paper data was summarized on the spore discharge from marine red algae, brown algae and some estuarine red algae along the coastal of Bay of Bengal.

Seasonal spore shedding

Algae which occur in marine water produce different types of spores and members of Rhodophyceae are perennial plants and members of the Phaeophyceae are seasonal and produce the spores certain months of the year only. Several authors (Srinivasa Rao, 1971; Rama Rao and Thomas,1974; Oza,1975; Umamaheswara Rao, 1976; Mohan Joseph and Krishna Murthy, 1977; Kaliaperumal and Umamaheswara Rao, 1982; Subba Rangaiah, 1983; 1985; Kaliaperumal and UmamaheswaraRao,1985;1986;UmamaheswaraRao,1987;NarasimhaRao,1989;1989b;Narasimha Rao and Umamaheswara Rao, 1991; Narasimha Rao and Subba Rangaiah, 1991; Narasimha Rao, 1992: Subba Rangaiah and Vanilla Kumari,1997;Narasimha Rao and Subba Rangaiah,2009; Narasimha Rao and Subba Rangaiah,2010) studied the seasonal spore shedding of marine red algae of coastal waters of East Coast of India. Some investigators(Umamaheswara Rao and Kalimuthu, 1972; Narasimha Rao, 1989; 1989b;1991;1995; Narasimha Rao and Subba Rangaiah,1991; Ganesan, et al, 2000; Narasimha Rao and Subba Rangaiah, 2010a; Narasimha Rao et.al. 2012; Subba Rangaiah et al,2012; Subba Rangaiah et al 2012a; Narasimha Rao,2014) studied the seasonal variations in the spore shedding of some marine brown algae along the east coast and west coasts of India. Spore shedding on estuarine algae of Indian estuaries investigated by few authors (Jagtap, 1985; Mal *et.al*. 1987; Narasimha Rao 1989; Narasimha Rao and Umamaheswara Rao, 1991; Narasimha Rao and Subba Rangaiah, 2007; Narasimha Rao *et.al*. 2008; Narasimha Rao and Murty, 2011; Narasimha Rao, 2016) .

Subba Rangaiah (1984) studied the Sporulation of tetraspore *Gracilaria textorii* for three months period only. Kaliaperumal and Umamaheswara Rao (1985 and 1986) studied the tetraspore output in *Pterocladia heteroplatos* and *Gelidium pusillum* which was ranging from 1149 to 10,78,505 spores /g.fr.wt./day. Narasimha Rao (1989) reported the seasonal sporulation in some marine red algae of Visakhapatnam coast waters. Narasimha Rao

(1989 b) studied the spore shedding in *Bangiopsis subsimplex,* Monospore production ranged from 1.2 and 2.2 millions spores /g.fr.wt. /day (). Similarly, the daily production of monospores from *Porphyra vietnamensis* ranged from 0.14 to 0.82 millions spores /g.fr.wt. /day (Narasimha Rao, 1992). Among the three members of ceramiales studied by Sudhakar and Subba Rangaiah (1997), spore shedding was observed in all months of the year. The tetraspore and carpospore shedding was maximum in two periods in both *Wrangelia argus* and *Centroceras clavulatum*, one in between January to February/March and the other between July to August/September. Among the three members of cryptonemiales studied (Subba Rangaiah and Vanilla Kumari, 1997), spore shedding was observed in all months of the year in *Amphiroa fragilissima, Jania rubens* and *Grateloupia lithophila*.

Narasimha Rao (1989) studied the seasonal spore shedding in *Ectocarpus mitchellae* at Visakhapatnam. Maximum plurispore output was $132X10^5$ and $126X10^5$ spores in 1984-85 and 1985-86 respectively. Maximum and minimum shedding of plurispores was correlating with seasonal growth of this brown alga. Narasimha Rao (1995) studied the seasonal spore shedding in *Rosenvingea nhatrangensis* growing at Visakhapatnam coast. Maximum number of spore shedding was observed in December and January (7, 84,972 and 6, 92,846 spores/g.f.wt./day respectively). Appa Rao (1998) studied the seasonal oospore shedding in *Sargassum ilicifolium* and *Sargassum vulgare* growing at Visakhapatnam coast and observed the maximum oospore shedding in *S.vulgare* was 3, 05,983 and in *S.ilicifolium* was 40,513. Ganesan et al. (2000) observed the tetraspore output in *Padina boergesenii* in December with maximum no of tetraspores was 19,260 spores/g.f.wt./day. Narasimha Rao el al (2012) studied the plusrispore shedding in Rosenvengea nhatrangensis occurs at Bhimili coast. Narasimha Rao (2014) studied the tetraspore shedding from Lobhophora variegata at Visakhapatnam and observed maximum spore shedding in the January with 1,92,458 spores /gram f.wt/day.

Narasimha Rao and Umamaheswara Rao (1991) reported the tetraspore and carpospores output from the estuarine red algae such as *Bostrychia tenella* and *Caloglossa leprieurii* estuarine waters of Godavari estuary. Shedding of tetraspores was observed throughout the year, but with seasonal difference in their output. Carpospores were liberated from October to May when the material was available. Narasimha Rao and Subba Rangaiah (2007) studied the spore liberation from *Caloglossa leprieurii* from estuarine regions of Sarada and Varaha estuaries. Tetraspore discharge was observed throughout the year with peak shedding in the months of December to February. Tetraspore output was varied from 14 to36 spores/stichidium/day. Higher numbers of carpospores (56 spores/stichidium/day) were liberated in the month of January and minimum number (39 spores/stichidium/day) in April. Narasimha Rao *et. al*. (2008) reported the tetraspore and carpospores output from the *Catenella impudica* in Godavari estuary at Bhiravapalem.

Effect of environmental factors on spore shedding

Data on the influence of the climatic and environmental parameters like light intensity, salinity and desiccation of marine algae was studied by several investigators (Subba Rangaiah *et.al*.,1975; Umamaheswara Rao and Kaliaperumal,1983; Umamaheswara Rao and Subba Rangaiah, 1986; Subba Rangaiah,1986;Kaliaperumal and Umamaheswara Rao,1987; Narasimha Rao,1989; Narasimha Rao,1989b; Narasimha Rao and Subba Rangaiah,1991; Narasimha Rao and Umamaheswara Rao, 1991; Sudhakar and Subba Rangaiah,1997; Subba Rangaiah and Vanilla Kumari, 1997; Narasimha Rao and Vanilla Kumari,1997;Narasimha Rao et al,2008). Subba Rangaiah *et.al* (1975) studied the tetraspore shedding of *Gracilaria corticata* at Visakhapatnam coast and observed that the spore output decreased with increase in the desiccation of fronds to air and maximum output was obtained under submerged conditions. Maximum shedding of tetraspores was found between 20 and 30‰. Spore output was maximum at '0' light intensity. Umamaheswara Rao and Subba Rangaiah,(1986)studied the tetraspore shedding from *Gracilaria textorii, Gracilariopsis sjoestedtii* and *Hypnea valentiae* from coastal waters of Visakhapatnam . Spore output was decreased with increased desiccation periods and maximum output was obtained under submerged conditions. Maximum shedding of tetraspores was found from 20 to 30 ppt salinity and spore output was maximum at '0' light intensity in *Gracilaria textorii, Gracilariopsis sjoestedtii and* maximum at light intensity of 750± 50 lux in *Hypnea valentiae.* Temperatures of 25 to 35◦ C were favorable for maximum liberation of spores for these algae. Information gathered by Subba Rangaiah (1986) on shedding of monospore from *Porphyra vietnamensis*, and was observed that Sporulation was recorded even when plants were exposed to air for four hours. Spore shedding was noticed from 10 to 60 ppt salinities with maximum output in salinities between 20 and 30 ppt. In different light intensities tested, maximum number of spores was liberated at 2,500 lux light intensity. Narasimha Rao and Subba Rangaiah (1991) studied the effect of salinity, light intensity and desiccation on monospore shedding from *Bangiopsis*

subsimplex, monospore and carpospores shedding from *Porphyra vietanamensis* at Visakhapatnam coast, and reported that that 30 to 40 ppt salinity, submergence of fronds and 27 to 44 µ E m^2 s^2 light intensity were found to be favorable conditions for the maximum spore shedding. Narasimha Rao and Umamaheswara Rao (1991) studied the effect of salinity and desiccation on the spore liberation from the two estuarine red algae *Bostrychia tenella* and *Caloglossa leprieurii occurring at Godavari estuary* near Kakinada. The maximum number of tetraspore and carpospores were liberated when the salinity was 20 ppt salinity and plants were in submerged condition.

Information on the effects of environmental factors such as desiccation, salinity, intensity of light and different industrial effluents on the liberation of various spores from the marine brown algae of Indian waters was collected by several authors (Umamaheswara Rao and Sanjeeva Reddy, 1982; Narasimha Rao, 1989b; Narasimha Rao and Subba Rangaiah,1991; Premila and Umamaheswara Rao,1997 and 1998; Murthy and Umamaheswara Rao,2003). In the experiments conducted by Umamaheswara Rao and Sanjeeva Reddy (1982) on tetraspore shedding in *Dictyota dichotoma* at Visakhapatnam coast, revealed that the spore output was decreased with increase in the exposure of fronds to air and maximum out put was obtained under submerged conditions of the fronds. Maximum shedding of tetraspores was observed in the salinities between 25 and 35‰. Minimum output was noticed in lower and higher concentrations of salinity. Similarly maximum number of tetraspores was liberated between temperatures of 25 to 30º C. Narasimha Rao (1989b) collected the information on effect of environmental factors on spore shedding from *Rosenvingea nhatrangensis* present at Visakhapatnam coast. Maximum number of plurispore out put was recorded when fronds were in submerged condition. Spore output was decreased with increasing time in the exposure to air and with minimum spores at 75 minutes of exposure. No spore shedding was reported beyond 75 minutes of exposure. Maximum plurispore out put was observed at 30‰ salinity. Spore out put was decreased from 30‰ salinity onwards and minimum at 50‰ salinity. Experiments conducted with different light intensities on plurispore shedding reveals that 1500 lux light intensity is favorable for maximum liberation of spores in *R. nhatrangensis*. Minimum number of plurispores shedding was reported at 500 and 2500 lux light intensities in this alga. Narasimha Rao and Subba Rangaiah (1991) studied the effect of environmental factors on the spore shedding in *Ectocarpus mitchellae* growing at Visakhapatnam coast. In their study, they reported that the maximum number of plurispores was liberated when fronds were in submerged condition. Minimum number of spores was reported at 60 minutes exposure and spore shedding completely ceased when fronds were exposed to 80 minutes and onwards. In the experiments conducted with different salinities, maximum plurispore out put was noticed at 30‰ salinity. No plurispore shedding was observed at 10 and 60‰ salinities. The effect of different light intensities is ranging from' o' (dark) to 97 µE m^2 s^1 on spore shedding indicates that maximum number of plurispores was observed at 27 µE m^2 s^1. Plurispore out put decreased from 27 µE m^2 s^1 onwards and there was no shedding at 79 µE m^2 s^1. Appa Rao (1995) studied the effect of environmental factors on tetraspore shedding in *Padina tetrastromatica* growing at Visakhapatnam coast. Maximum number of tetraspores were released when fronds in submerged state and the spore output was decreased slowly as the period of exposure increased and the liberation of spores was seen up to 6 hours in this alga. Optimum tetraspore shedding was noticed at 30‰ salinity and 500 lux light intensity. Working with the species of *Sargassum ilicifolium* and *Sargassum vulgare*, Appa Rao (1998) observed that maximum number of oospores were liberated when receptacles in the submerged condition. Among the various salinities tested, 20 and 30 ‰ salinities are found to be favorable for maximum liberation of oospores. And peak shedding of oospores was found at 25 ºC temperature.

Premila and Umamaheswara Rao (1998) studied the effect of petroleum refinery and fertilizer factory effluents on marine brown algae such as *Padina tetrastromatica* and *Dictyota dichotoma.* Spore shedding was observed in all concentration of V.R.F. (Visakha petroleum Refinery) from 10 to 100%. In *Padina tetrastromatica* and *Dictyota dichotoma*, spore out put was decreased from 20% concentration. Minimum number of tetraspores was liberated from 30% onwards. No spore discharge was recorded beyond 100%. In *Dictyota dichotoma* spore shedding was also reported in all concentration of C.F.E (Coromandel factory effluent). Maximum number of spores was liberated at control and 25% concentration of effluent. Beyond, 25% concentration no spore discharge was observed. Murthy and Umamaheswara Rao (2003) collected the information on effect of industrial wastes on the growth and reproductive stages of macro algae of Visakhapatnam coastline, east coast of India. Studies were carried out on spore shedding of *Padina tetrastromatica* and *Sargassum polycystum* in different concentration of industrial wastes. The effect of only two wastes (Hindustan zinc effluent and Alum factory effluent) on tetraspore shedding of Padina indicates that median effective concentrations (24 Ec 50 values) of all the wastes, estimated for the spore liberation in *P.*

tetrastromatica. Spore out put decreased rapidly from 2.0 -10.5 %in different effluents tested. There was no spore discharge after 60% in P. tetrastromatica.

CONCLUSIONS

Studies conducted by the several authors revalidated that the growth period in some of the algae was coincided with the low temperature moderate salinities of the sea water. Similarly the seasonal spore shedding is also coincided with the maximum growth periods. More number of spores was observed in seasonal algae and less number of spores in the algae which appears throughout the year. Regarding the effect of environmental factors on spore shedding, submerged conditions of plants, moderate saline conditions and low light intensity and low temperatures (25 to 30◦ C) are favorable for the maximum spore liberation.

Species of the marine brown algae are seasonal forms which occur from the month of October to April or May on the rocky surfaces of the intertidal regions. Seasonal spore output was higher during the months of December and January and spore shedding coincided with the maximum growth periods of the algae. More number of spores was liberated from the brown algae than the red algal members. Regarding the effect of environmental factors on spore shedding, it was observed that salinity in between 20 and 30‰, low light intensity; submerged conditions of the fronds are favorable factors for the maximum liberation of spores.

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