



Studies on marine algae of Andhra Pradesh : A Review

N. KALIAPERUMAL¹ AND V.S.K.CHENNUBHOTLA²

Central Marine Fisheries Research Institute, Kochi - 682 018, Kerala, India

Present Address :

¹N-163, Maya Indraprastha, Kanakapura Main Road, Bangalore-560078, Karnataka, India

²Plot No. 597, Vaidehi Nagar, Vsanthapuram, Hyderabad-500 070, Andhra Pradesh, India

ABSTRACT

Studies on marine macro algae of Andhra Pradesh started in 1950's. The research work carried out by different organisations and several researchers on various aspects of seaweeds such as distribution & diversity, resources, systematics, ecology, biology, spore shedding, biochemicals, phycocolloids, pollution, culture and utilization are reviewed in this paper.

Introduction

Marine macro algae from one of the important living resources of the sea. Marine algae contain different vitamins, minerals, trace elements, protein, iodine etc. They also contain essential amino acids needed in the human diet. The marine macro algae directly or indirectly play an important role in the economy of the maritime states. The marine macro algae are used as food for human, animal feed, fodder, fertilizers and sources of various chemicals, as raw materials for biofuel production and liquid fertilizer. Selected green, brown and red algae form part of the diet taken by people of South East Asia. In India, the red alga *Gracilaria edulis* is consumed in certain coastal areas of Tamil Nadu as porridge. Some of the marine algal constituents are of antimicrobial, antifungal, antiviral, diuretic and spasmolytic value. The algae are used in the treatment of goitre and as ichthyotoxic compounds. The high fibre content of the marine macroalgae acts as a soil-conditioner and the mineral content as

fertilizer. In the recent past, marine macroalgae have also been gaining momentum as new experimental materials for biological research and integrated aquaculture systems. (Kaliaperumal, 2000; Umamaheswara Rao, 2011; Chennubhotla *et al.*, 2000, 2013a & b).

The coastline of Andhra Pradesh extends from Tada, Pulicat Lake on south to Domkura near Kalingapatnam on the north. The coast has rocky substratum in some places and in all other places it is sandy or muddy. The coast offers ideal environment for marine algal communities with two big rivers Godavari and Krishna opening into Bay of Bengal and highly productive mangrove habitats occur in the river deltas. The research works carried out by different organisations and researchers on various aspects of marine algae of Andhra Pradesh are given below.

Distribution and Diversity

Andhra Pradesh is an important state among

the seaweed growing maritime states in India. The coastline of Andhra Pradesh extending from Ichapuram or Sompeta in the north to Pulicat Lake in the south is about 970 km long. The northern Andhra Pradesh comprising east Godavari, Visakhapatnam and Srikakulam district is rich in algal resources and algae are much less abundant southwards. Outcrops of rocky boulders with less dense growth of various kinds of seaweeds occur in the northern parts of Andhra Pradesh, roughly extending from Sompeta down to Rombilli area (Umamaheswara Rao, 1978). In general, agrarophytic resources are less, whereas *Sargassum* species are more abundant in different localities of the coastline. The economically and commonly distributed seaweeds along the coastline are *Ulva fasciata*, *Enteromorpha compressa*, *Caulerpa taxifolia*, *Chaetomorpha antennina*, *Cladophora fritshii* (green algae) *Sargassum vulgare*, *Sargassum polycystum*, *Dictyota dichotoma* (brown algae), *Gelidium pusillum*, *Pterocladia heteroplata*, *Gracilaria corticata*, *Gracilaria* spp., *Porphyra vietnamensis*, *Hypnea valentiae*, *Grateloupia* spp and *Laurencia* spp. The distribution and diversity of macroalgae in relation to environmental factors at Visakhapatnam coast was studied by Sarojini *et al.* (2013a).

Resources

The Andhra Pradesh coast was surveyed by the Central Salt & Marine Chemicals Research Institute in collaboration with the Department of Fisheries, Government of Andhra Pradesh during 1972 - 1982. The standing crop was found to be about 7500 tons fresh weight (Anon, 1984; Rama Rao, 2009). In the survey carried out along northern Andhra Pradesh coast (Chennubhotla, 1992) 1450 tons (fr. Wt.) of standing crop of algae comprising the species of *Ulva fasciata*, *Enteromorpha compressa*, *Chaetomorpha antennina*, *Sargassum* sp. *Padina* sp., *Gracilaria corticata*, *Gelidium* sp., *Hypnea valentiae* and *Grateloupia lithophila* was estimated. Kaliaperumal and Umamaheswara Rao (1981) studied the standing crop of agar yielding seaweeds *Gelidium pusillum* and *Pterocladia*

heteroplata growing at Visakhapatnam coast. The density fresh weight of the standing crop of these two algae varied from 0.489 to 1.295 kg/m² and the dry weight from 0.233 to 0.522 kg/m². The mean density of the crop was more or less similar in these two species. Sarojini *et al.* (2013 a, b) studied the distribution diversity and biomass of macro algae in relation to environmental factors at Visakhapatnam coast. The seasonal variations in distribution and biomass of 5 species of chlorophyceae at Visakhapatnam was given by Sarojini and Sujatha (2014).

Floristics and Systematics

The marine algal taxonomy in India was reviewed by Kaliaperumal (1999). Totally 122 species of marine algae have been recorded from Andhra Pradesh coast by different workers in different seasons (Umamaheswara Rao and Sreeramulu, 1970 a; Subba Rao *et al.*, 1983; Anon, 1984; Chennubhotla, 1992; Sarojini *et al.*, 2013 a, b). An annotated list of 80 algae growing along the Visakhapatnam coast was published by Umamaheswara Rao and Sreeramulu (1970a). In the systematic list of marine algae from Andhra Pradesh published by Subba Rao *et al.* (1983) 98 species of algae comprising 30 species of green algae, 23 species of brown algae, 44 species of red algae and 1 species of blue-green alga were given. In the survey conducted by the CSMCRI and Dept. of Fisheries, Govt. of Andhra Pradesh, 23 species of green algae, 7 species of brown algae and 34 species of red algae were recorded (Anon, 1984). Sarojini *et al.* (2013 a) recorded 40 species of algae from three stations along Visakhapatnam, of which 17 species belonged to Chlorophyceae, 1 to Xanthophyceae, 7 to Phaeophyceae and 15 to Rhodophyceae. The stray collections of algae were also reported from Andhra Pradesh Coast by Umamaheswara Rao. The genus *Pterocladia* (Rhodophyceae) from Visakhapatnam coast was reported for the first time in India by Umamaheswara Rao and Kaliaperumal (1980).

Ecology

Ecological, auto-ecological and eco-

physiological studies of marine algae of Andhra Pradesh coast were made by some workers (Umamaheswara Rao, 1964, 1990; Subbrangaiah, 1978; Kaliaperumal, 1979; Narasimha Rao, 1984, 1989a; Mary Bharathi, 1987). Umamaheswara Rao and Sreeramulu (1963) described the vertical distribution and seasonal variation in the growth of *Porphyra vietnamensis* observed in 1961 along Visakhapatnam coast. Sreeramulu first reported this edible red alga during May to August in 1952. Umamaheswara Rao observed its period of occurrence as March to May 1961 and January to April in 1962 along Visakhapatnam coast. It is a protein rich alga which is a staple food item in Japan, China, Korea etc. In later years, this alga was found growing in small quantities with a density of 1.92 g/m² along Visakhapatnam. These variations observed in the growth period of this alga on the same coast have been attributed to the variations in environmental factors in the intertidal region in different years.

Ecological study of intertidal algae of Visakhapatnam coast was made by Umamaheswara Rao and Sreeramulu (1964, 1974). In this study, data were collected on the annual growth variations of *Ulva fasciata*, *Enteromorpha compressa*, *Caulerpa fastigiata*, *C. racemosa*, *C. sertularioides*, *C. taxifolia*, *Padina tetrastomatica*, *Dictyota* sp., *Sargassum ilicifolium*, *S. Tenerrimum*, *S. turneri*, *S. vulgere*, *Geledium* spp, *Gracilaria* sp., *Gelidiopsis variabilis*, *Hypnea* sp., *Acanthophora spicifera* and *Pophyra vietnemensis*. Recolonization studies were made by Umamaheswara Rao and Sreeramulu (1968) on Visakhapatnam coast by clearing areas of 0.5 m² in the *Gracilaria corticata* bed. The sequence of colonization was followed for a period of five months. *Ulva* and *Enteromorpha* were seen as first colonizers and fresh germlings of *Gracilaria corticata* reappeared in the denuded areas after few months. A quantitative study on intertidal zonation at Visakhapatnam was made by Narasimha Rao (1984). Numerical study of intertidal zonation along Visakhapatnam was made by Narasimha Rao and

Umamaheswara Rao (1986), Narasimha Rao and Prasanna Lakshmi (2009) and Prasanna Lakshmi and Mohan Narasimha Rao (2009).

Biology

The biology of the economically important Indian seaweeds was reviewed by Chennubhotla *et al.* (1987). Detailed studies on the seasonal growth, phenology and spore shedding in red algae such as *Gelidiopsis variabilis* (Kaliaperumal and Umamaheswara Rao, 1982), *Gracilaria corticata* (Subbrangaiah, 1983a), *Hypnea valentiae* (Subbrangaiah and Umamaheswara Rao, 1983), *Gracilaria textorii* (Subbrangaiah, 1984a), *Pterocladia heteroplotos* (Kaliaperumal and Umamaheswara Rao, 1985), *Gracilaria sjoestedtii* (Subbrangaiah, 1985a), *Agalothanion cordatum* (Subbrangaiah, 1985b), *Gelidium pusillum* (Kaliaperumal and Umamaheswara Rao, 1986), *Grateloupia filicina* (Umamaheswara Rao, 1987), *Bangiopsis simplex* (Narasimha Rao, 1989b), *Amphiroa fragilissima* (Subbrangaiah and Vanilla Kumari, 1997a), *Wrangelia argus* (Subbrangaiah *et al.*, 2002), *Polysiphonia platyearpa* (Subbrangaiah *et al.*, 2003a), *Centroceras clavulatum* (Subbrangaiah *et al.*, 2003b), *Porphyra vietnemensis* (Narasimha Rao, 1992; Narasimha Rao and Subbrangaiah 2010a) and brown algae *Padina tetrastomatica* and *Dictyota dichotoma* (Umamaheswara Rao and Sreeramulu, 1970b), *Ectocarpus mitchalle* (Narasimha Rao, 1991), *Sargassum vulgare* (Subbrangaiah and Appa Rao, 2004), *Sargassum polycystum* (Srinivasa Rao and Umamaheswara Rao, 2002), *Rosenvingea nhatragensis* (Narasimha Rao *et al.*, 2012) and *Lobophora variegata* (Narasimha Rao, 2014). Satya rao *et al.* (2011) made seasonal studies on marine algae of bhimili coast.

From the information obtained on the variation in growth of the above algae growing in different localities along Andhra Pradesh coast, it may be mentioned that the life span of many seaweeds is limited to one year or for a short periods of the year. Every year fresh plants develop from the

reproductive bodies liberated by the plants of the previous generation or from the perennial basal portions of old plants. The periods of regeneration, maximum growth and decline vary from species to species and also from one locality to the other. In some seaweeds, two peak growth periods with a half yearly growth cycle was observed while in other seaweeds only a single peak growth period was observed. In general, maximum growth was observed in many seaweeds in two seasons of the years, one from June to August and the other from November to January. The economically useful seaweeds should be collected only during peak growth periods in order to get more quantity of raw materials and better yield of finished products. The studies conducted on the periods of reproduction showed that the fruiting behavior varied in different seaweeds growing along Andhra Pradesh coast. Though reproduction was observed throughout the year, in many cases two fruiting seasons were seen in a year and one fruiting season for other species. The information collected on the spore output from the above mentioned algae shows that the number of spores produced by an alga is enormous and they can be successfully raised into germlings in the laboratory or nursery and then to harvestable size plants by transplantation to the sea. The spore output season and the period of maximum sporulation varied from species to species. Narasimha Rao and Subbarangaiah (2009 and 2010b) reviewed the spore shedding in marine red and brown algae of Indian coast.

Diurnal periodicity in spore shedding

Data have been collected on the periodicity or rhythmic liberation of spores in *Polysiphonia platycarpa* (Subbarangaiah and Sudhakar, 1977), *Gelidium pusillum*, *Pterocladia heteroplatos* and *Gelidiopsis variabilis* (Umamaheswara Rao and Kaliaperumal, 1987a). *Wrangelia argus* and *Centroceras clavulatum* (Sudhakar and Subbarangaiah, 1993) and *Rosenvingae nhatrangensis* (Narasimha Rao, 1995). The rhythm of spore shedding from some marine algae was

published by Narasimha Rao and Subbarangaiah (1991) and Subbarangaiah (2005, 2006). Periodicity of rhythmic liberation of spores was observed in some algae, while there was no such periodicity in the shedding of spores in other algae.

Effects of environmental factor on spore output and their diurnal periodicity

A number of studies were made on the effects of environmental factors such as desiccation, salinity, temperature and light on the spore output in many red and brown algae by several workers (Subbarangaiah *et al.*, 1975; Subbarangaiah and Vanilla Kumari, 1977, Umamaheswara Rao and Subbarangaiah, 1981, 1988; Umamaheswara Rao and Sanjeeva Reddy, 1982; Umamaheswara Rao and Kaliaperumal, 1983; Subbarangaiah, 1985c, 1986; Kaliaperumal and Umamaheswara Rao, 1987; Umamaheswara Rao and Kaliaperumal, 1987b; Umamaheswara Rao and Subbarangaiah, 1988; Narasimha Rao, 1989c; Kaliaperumal, 1990a, 1990b; Subbarangaiah *et al.*, 2012a, 2012b). The germination of spores and their early stages of development were studied in *Dityota dichotoma* (Umamaheswara Rao and Sanjeeva Reddy, 1982), *Hypnea valentia* (Subbarangaiah, 1983b, 1988) and *Gracilaria textorii* (Subbarangaiah, 1984, 1985d).

Biochemicals and Phycocolloids

Studies were made on mineral contents, biochemical composition, Vitamin - C, D, E, B-Complex Vitamins, B-carotene, fatty acid, poly-unsaturated fatty acids, flavonoids, phenol and photosynthetic pigments in many marine algae by some workers (Sarojini and Sharma, 1999; Sarojini and Subbarangaiah, 1999; Srinivasa Rao and Umamaheswara Rao, 2004; Sarojini and Lakshminarayana, 2009a, b, 2001 a,b,c, 2012, 2013, 2014; Sarojini *et al.*, 2012; Narasimha Rao and Pragaya Murthy, 2012; Sarojini and Uma Devi, 2014; Sarojini *et al.*, 2013c, 2015; Sarojini and Sujatha, 2015). The antioxidant activities of ethanolic extracts of two brown algae were investigated by Sarojini *et al.* (2013c). The antimicrobial activity of *Caulerpa*

taxifolia (Manjula and Narasimha Rao, 2014), *Gelidium pusillum* and *Centroceras clavulatum* (Kausalya and Narasimha Rao, 2015a, 2015b) were also investigated.

The phycocolloid contents of some red and brown algae of Visakhapatnam coast were also studied. Umamaheswara Rao (1978) analysed the alginic acid content of five species of brown algae and their yield is given below.

Seaweed	Alginic acid %
<i>Sargassumilicifolium</i>	34.93
<i>Sargassummyriocystum</i>	32.34
<i>Sargassumvulgare</i>	25.46
<i>Padina tetrastromatica</i>	23.34
<i>Dictyota dichotoma</i>	21.79

The agar content and properties in *Gracilaria* and *Gelidium heteroplatos* (Umamaheswara Rao, 1978), *Gelidium pusillum* and *Pterocladia heteroplateos* (Kaliaperumal and Umamaheswara Rao, 1981) were investigated. The results obtained are given below.

The effect of pH on the yield and physiological properties of agar extracted from *Gelidium pusillum* and *Pterocladia heteroplatos* was studied (Kaliaperumal and Umamaheswara Rao, 1981). In general, there were no marked differences in the yield, gel strength, gelling and melting temperatures of the agar extracted in the acidic and alkaline pH ranging from 5 to 10. However, the melting temperature values were not uniform in both these algae and the gel strength was slightly more in the alkaline pH.

Pollution

Some studies were made on the effect of pollution on the marine algae of Visakhapatnam coast (Narasimha Rao, 1994). Premila and Umamaheswara Rao (1997) studied the effect of crude oil on the growth and reproduction in some benthic marine algae. The effect of refinery and fertilizer factory effluents on the marine algae was investigated by Premila and Umamaheswara Rao (1988). The effect of industrial effluents on the growth, reproductive stages, photosynthesis and respiration of macro algae of Visakhapatnam coast was studied by Balakrishnamurthy (1989), Murthy and Umamaheswara Rao (2003) and Umamaheswara Rao and Murthy (2011).

Culture

It is necessary to augment the supply of seaweed raw materials to the seaweed based industries as the resource from the natural seaweed beds is not sufficient to meet the requirements for the production of different value added seaweed products. Hence, attempts have been made for more than five decades by the Central Marine Fisheries Research Institute, Central Salt & Marine Chemicals Research Industries, Centre of Advanced Study in Botany, University of Madras, Aquaculture Foundation of India, Chennai and other Government 7 Non-Government organisations to culture some of economically important marine macro algae such as *Gracilaria edulis* and *Gelidiella acerosa* (agarophytes), *Kappaphycus alvarezii* and *Hypne musiformis* (Carrageenophytes), *Acanthophora spicifera* (agaroidophytes), *Sargassum* spp

Species	Yield (%)	Gel strength (g/cm ²)		Gelling temp (°C)	Melting temp (°C)
		1.0 % concentration	1.5% concentration	1.5 % Concentration	1.5 % Concentration
<i>Gracilaria corticata</i>	44.64	64	134	-	-
<i>Gelidium hetroplates</i>	15.57	297	602	-	-
<i>Gelidium pusillum</i>	50.0	175	276	38	86
<i>Pterocladia heteroplatus</i>	35.1	167	288	38	83

(alginophytes), *Enteromorpha flexuosa* and *Ulva fasciata* (edible green algae) by vegetative propagation methods in the laboratory using spores. In the field cultivation of seaweeds carried out in the coastal waters of Tamil Nadu, Gujarat and Lakshadweep islands, encouraging results were obtained (Kaliaperumal, 1993, 2006 a, b, 2015; Subba Rao *et al.*, 2004; Subba Rao and Ganesan, 2006; Eswaran *et al.*, 2006; Subbaramaiah *et al.*, 2008).

Field cultivation of *Gracilaria corticata*, *Gracilaria verrucosa* and *Hypnea valentiae* was tried in the coastal water of Lawson's Bay of Visakhapatnam. But the trials were not successful due to high wave action and wind. The tissue culture technique was attempted to culture *Gelidiella acerosa* and *Sargassum polycystum* in the laboratory by inducing callus using PES culture medium (Umamaheswara Rao, 1995; Umamaheswara Rao and Srinivasa Rao, 1996; Srinivasa Rao, 1998). From single explants of *Gelidella acerosa* and *Sargassum polycystum* many shoots like structures developed on agar media. In *Sargassum polycystum* profusely branched shoots were formed within 2 to 3 months of culture. Excised pieces of these shoots when cultured in liquid medium gave normal young plants or germlings. These results indicated the possibility of obtaining steady seed materials or plantlets through micropropagation. Chennubhotla (2000) also carried out tissue culture experiments with some economically important agarophytes *Gracilaria edulis* and *Gracilaria corticata* and alginophyte *Sargassum vulgare* at Visakhapatnam Regional Centre of Central Marine Fisheries Research Institute and obtained encouraging results with callus formation in *Gracilaria corticata* and *Sargassum vulgare* and in vitro multiple shoot formation in *Gracilaria edulis* and *Sargassum vulgare* from young leafy explants.

The growth studies on some intertidal algae of Visakhapatnam coast were made in the laboratory by Srinivasa Rao (1998). The effect of environmental factors on the growth of *Gracilaria corticata* by

Srinivasa Rao and Umamaheswara Rao (1998) and the effect of temperature, photon flux density and salinity on the growth of *Sargassum polycystum* by Srinivasa Rao and Umamaheswara Rao (1999) were studied. The interaction of salinity and photon flux density on the growth of six marine algae under laboratory conditions was investigated by Srinivasa Rao and Umamaheswara Rao (1999a, b).

Pilot scale field cultivation of the carrageenan yielding seaweed *Kappaphycus alvarezii* has been initiated in April, 2015 in the coastal areas of Andhra Pradesh viz. Chelapa Thimmapuram and Mangamaripeta (Visakhapatnam District), Mukkam, Yerra Mussarayapalem and Neelagaddapeta (Vijayanagaram District) (Periyasamy and Subba Rao, 2015). Among these five locations, four harvests were made at Thimmapuram and in other locations cultivation is going on except Neelagaddapeta. The tubular model and net bag methods were adopted for cultivation. These experiments were carried out to study the feasibility of *Kappaphycus alvarezii* cultivation in Andhra Pradesh. The crop yields were recorded after every 45 days for the period of 6 months from April to September, 2015. The maximum biomass of 47.82 ± 2.23 kg fr. wt/10 m line and 56.25 ± 3.13 kg fr. wt/10 m line were obtained in tubular and net bag methods respectively. The harvested dried material of *Kappaphycus alvarezii* was analysed for carrageenan yield and its physical property i.e., gel strength. The yield and quantity of carrageenan were comparable to that of Tamil Nadu coast. This study has indicated that commercial cultivation of *Kappaphycus alvarezii* can be done successfully in Andhra Pradesh coast.

Utilisation

Only a very few attempts were made on utilization aspects of marine algae of Andhra Pradesh coast. Narasimha Rao and Prasanna Lakshmi (2014a) studied the effect of seaweed liquid fertilizer on seed germination and productivity of some vegetable crops. Experiments were also conducted on the effect of seaweed liquid fertilizer from

Gracilaria textorii and *Hypnea musciformis* on seed germination and productivity of some vegetable crops (Narasimha Rao and Reshmi Chatterjee (2014b).

Conclusion

It is evident from the foregoing account that a good amount of research works was carried out by many researchers on various aspects of marine algae of Andhra Pradesh coast for the last six decades. So for many research papers on various aspects of marine algae of Andhra Pradesh coast have been published in reputed and referred international and Indian Journals. Information available on species diversity and standing crops of seaweeds clearly shows that Andhra Pradesh coast supports rich marine algal resources of economic value and it could be utilised for producing several value added seaweed products.

Recommendations

- ❖ Survey of marine algal resources in the intertidal, shallow waters and deep waters of Andhra Pradesh should be conducted to estimate the present standing crop for commercial exploitation and utilisation by the Indian seaweed industries for the production of agar, agarose, carrageenan, alginates and other value added seaweed products.
- ❖ Installation of artificial reef structures must be done in the coastal waters of Andhra Pradesh for facilitating settlement of spores and regeneration to adult plants.
- ❖ Ecological studies on the growth, fruiting behaviour and spore shedding of economically important seaweed growing in all the other seaweed growing areas of Andhra Pradesh must be carried out for proper utilization of the available resources and for cultivation of these seaweeds since much work have been done on the above aspects on the seaweeds growing at Visakhapatnam coast.
- ❖ The biofuel potential of marine algae occurring along Andhra Pradesh coast is worthwhile

investigating by converting the cellulose and other polysaccharides into ethanol.

- ❖ Detailed investigation on the biochemical, phycocolloids constituents and utilisation of marine algae of Andhra Pradesh, may be given due importance.
- ❖ Extraction of bioactive compounds from the seaweeds of Andhra Pradesh coast for producing pharmaceutical products of medical and dental value.
- ❖ Establishing of seaweed industries in Andhra Pradesh for utilising the marine algal resources available in the coastal areas as raw materials.
- ❖ Commencement of commercial scale cultivation of carrageenan yielding *Kappaphycus alvarezii* and other seaweeds should be undertaken in suitable localities along the Andhra Pradesh involving the fisherfolk and coastal people. This not only augment the supply of seaweeds to the industries, but also provide employment opportunities to the coastal population which will improve their economic condition and thus help in the rural upliftment.
- ❖ Conducting of demonstration and training programmes to the coastal people to create awareness on seaweeds, their cultivation and utilisation.
- ❖ Entrepreneurs should come forward the carryout the above recommendations taking guidance of scientists of research institutions to augment the standing crop of natural resources and culturing some of the useful marine macro algae growing along Andhra Pradesh coast or by transplantation from other coastal areas.

Acknowledgement

The authors are grateful to Prof. G.Subbarangaiah, Former Head, Department of Botany and Department of Microbiology, Andhra University, Visakhapatnam; Dr. G.M. Narasimha Rao, Assistant Professor, Department of Botany, Andhra University, Visakhapatnam; Dr. Y. Sarojini, UGC Women Scientist, Department of Botany, Andhra

University, Visakhapatnam and Dr. A. Srinivasa Rao, Lecturer-in-Charge, Department of Botany & Microbiology, Pithapur Rajah's Govt. College (Autonomous), Kakinada for providing the particulars about their Ph.D. theses and list of their papers published. They are also thankful to Dr. C.Periyasamy, Vice-President, Aquaculture Foundation of India, Chennai, Tamil Nadu for providing information on *Kappaphycus alvarezii* cultivation in Andhra Pradesh coast and to Dr. K.Subbaramaiah, Former Scientist-in-Charge, Marine Algal Research Station (CSMCRI), Mandapam Camp, Tamil Nadu for critically going through this paper. The authors are also thankful to Dr. M. Ganesan, Senior Scientist, Marine Algal Research Station (CSMCRI), Mandapam Camp, Tamil Nadu for his keen interest and encouragement and to Shri. S.Narasimman, Research Scholar, Department of Botany, Annamalai University, Annamalai Nagar for his secretarial assistance in the preparation of this paper. The senior author Dr. N. Kaliaperumal dedicates this paper to beloved and respected Prof. M.Umamaheswara Rao (late), was his Ph.D. Director of Research and in various aspects of research carried out in the field of marine algae of Andhra Pradesh.

References

- Anon 1984. *A report on the survey of Marine Algal Resources of Andhra Pradesh, 1979-1982*. Central Salt & Marine Chemical Research Institute, Bhavnagar. 30 p.
- Balakrishnamurthy, S. 1989. *Effect of industrial effluents on some macroalgal forms*. Ph.D. Thesis, Andhra University.
- Chennubhotla, V.S.K. 1992. *A survey of seaweed resources of Andaman-Nicobar islands, Visakhapatnam - Chilka lake region and Lakshadweep groups of islands*. Final report on the ICAR-Ad-hoc Scheme. 104 p.
- Chennubhotla, V.S.K. 2002. *Final report of the ICAR Ad-hoc scheme Tissue culture of some economically important seaweeds*. 30 p.
- Chennubhotla, V.S.K., N. Kaliaperumal, S. Kalimuthu and P.V.R. Nair 1987. Biology of the economically important Indian seaweeds. *Seaweed Res. Utiln.*, 10(1):21-32.
- Chennubhotla, V.S.K., M. Umamaheswara Rao and K.S.Rao 2013a. Exploitation of marine algae in Indo-Pacific region. *Seaweed Res. Utiln.*, 35(1&2):1-17.
- Chennubhotla, V.S.K., M. Umamaheswara Rao and K.S.Rao 2013b. Commercial importance of marine macro algae. *Seaweed Res. Utiln.*, 35(1&2):118-128.
- Chennubhotla, V.S.K., N. Kaliaperumal, Reeta Jayasankar, S. Kalimuthu, J.R. Ramalingam, K. Muniyandi and M.Selvaraj 2000. Seaweeds. In : *Marine Fisheries Research and Management*, CMFRI Special Publication. pp.21-37.
- Eswaran, K., P.K. Ghosh, P.V. Subba Rao and O.P. Mairh 2006. Field cultivation of *Kappaphycus alvarezii* in India. In : *Recent advances of applied aspects of Indian marine algae with reference to global scenario*. Vol. 1. A. Tewari (ed). CSMCRI, Bhavnagar. pp.250-261.
- Kaliaperumal, N. 1979. *Ecological studies on some red algae of the Visakhapatnam coast*. Ph.D. Thesis, Andhra University. 134 p.
- Kaliaperumal, N. 1990a. Effect of environmental factors on diurnal periodicity of tetraspore output in some red algae of Visakhapatnam coast. *Seaweed Res. Utiln.*, 12(1&2):87-95.
- Kaliaperumal, 1990b. Influence of low and high temperature on diurnal periodicity of tetraspore shedding in some red algae. *J. Mar. Biol. Ass. India*, 32(1&2):259-263.
- Kaliaperumal, N. 1993. Seaweed culture. In : *Handbook on aqua farming entitled "Seaweed Sea urchin and Sea cucumber*. MPEDA. pp.9-22.
- Kaliaperumal, N. 1999. Marine algal taxonomy in India. In : *Recent Trends in Algal Taxonomy*. Vol. 1. *Taxonomical Issues*, Vidhyavathi and A.K. Mahatol (eds.), A.P.C. Publication Pvt. Ltd., New Delhi. pp.275-285.
- Kaliaperumal, N. 2000. Seaweed their culture, products and applications. In : *Manual for Summer School on Recent Advances in Marine Biotechnology*. CIFE, Mumbai. pp.139-145.
- Kaliaperumal, N. 2006a. Culture of *Gracilaria edulis* and other seaweeds in India. In : *Recent Advances on Applied Aspects of Indian Marine Algae with reference to Global Scenario*. A. Tewari (ed), CSMCRI, Bhavnagar, pp.94-108.

- Kaliaperumal, N. 2006b. Seaweed cultivation. In : *Handbook of Fisheries and Aquaculture. Directorate of Information and Publication of Agriculture, Indian Council of Agricultural Research, New Delhi.* pp. 430-437.
- Kaliaperumal, N. 2015. Methods of Cultivation and Economic Values of Seaweeds. In : *Advances in Marine and Brackish water Aquaculture.* Santhanam Perumal, A.r. Thirunavukkarasu and Perumal Pachiappan (eds.), Springer, India. pp. 209-215.
- Kaliaperumal, N. and M. Umamaheswara Rao 1981. Studies on the standing crop and phycocolloid of *Gelidium pusillum* and *Pterocladia heteroplates*. *Indian J. Bot.*, 4(2): 91-95.
- Kaliaperumal, N. and Umamaheswara Rao 1982. Seasonal growth and reproduction of *Gelidiopsis variabilis* (Greville) Schmitz. *J. Exp. Mar. Biol. Ecol.*, 61 : 265-270.
- Kaliaperumal, N. and M. Umamaheswara Rao 1985. Seasonal growth, reproduction and spore shedding in *Pterocladia heteroplates*. *Proc. Indian Acad. Sci., (Plant Sci.)* 94 (4-6): 627-632.
- Kaliaperumal, N. and M. Umamaheswara Rao, 1986. Growth, reproduction and sporulation of marine alga *Gelidium pusillum* (Stackhouse) Le jolis. *Indian J. Mar. Sci.*, (15(1)): 29-32.
- Kaliaperumal, N. and M. Umamaheswara Rao, 1987. Effect of thermal stress on spore shedding in some red algae of Visakhapatnam coast. *Indian J. Mar. Sci.*, 16(3): 201-202.
- Kousalya, M. and G.M. Narasimha Rao 2015a. Antimicrobial activity of marine algae. *J. Algal Biomass Utiln.*, 6(1): 78-87.
- Kousalya, M. and G.M. Narasimha Rao 2015b. Antimicrobial activity of *Gelidium pusillum* and *Centroceras clavulatum* from Visakhapatnam coast, India. *J. Algal Biomass Utiln.*, 6(1): 40-48.
- Manjula, E. and G.M. Narasimha Rao 2014. In vitro study of antimicrobial activity in marine algae *Caulerpa taxifolia* and *Caulerpa racemosa*. *Int. J. App. Biol. Pharma. Technol.*, 5(2): 57-62.
- Mary Bharathi 1987. *Seasonal growth studies on some marine macro algae.* M.Phil. Dissertation, Andhra University.
- Murthy, S.B.K. and M. Umamaheswara Rao 2003. Effect of industrial waters on growth and reproductive stages of macroalgae of Visakhapatnam coastline, east coast of India. *Indian J. Mar. Sci.*, 32:57-66.
- Narasimha Rao, G.M. 1984. *A quantitative study on intertidal zonation at Visakhapatnam.* M.Phil. Dissertation. Andhra University. 49 p.
- Narasimha Rao, G.M. 1989a. *Ecological studies on some estuarine and marine algae.* Ph.D. Thesis. Andhra University. 129 p.
- Narasimha Rao, G.M. 1989b. Seasonal growth, photosynthesis and spore shedding of *Bangiopsis subsimplex* (Mont.) Schmitz. *Mahasagar*, 22(3): 143-146.
- Narasimha Rao, G.M. 1989c. Effect of environmental factors on spore shedding from *Rosenvingea nhatrangensis* Dawson. *Mahasagar*, 22(3): 135-137.
- Narasimha Rao, G.M. 1991. Seasonal growth and spore shedding of *Ectocarpus mitchellae* (Harv.) Hamel. *Mahasagar*, 24(1): 59-62.
- Narasimha Rao, G. M. 1992. Seasonality in growth, reproduction, and spore liberation of *Porphyra vietnemensis*. Tanaka et Ho. (Rhodophyta, Bangiales). *Mahasagar*, 25: 11-17.
- Narasimha Rao, G. M. 1994. Algological observations from polluted areas of Visakhapatnam, East coast of India. *Ind. J. of Landscape Systems*, 17(2): 35-38.
- Narasimha Rao, G. M. 1995. Seasonal variation and diurnal periodicity in spore liberation from *Roservingea nhatrangensis* Dawson. *Phykos*, 34(1&2): 145-148.
- Narasimha Rao, G. M. 2014. Seasonal growth and spore shedding in *Labophora variegata* (Lamouroux) Womersley ex Oliveria from Bhimila, Andhra Pradesh. *Indian. J. Algal Biomass Utiln.*, 5(4): 9-11.
- Narasimha Rao, G. M. and M. Umamaheswara Rao 1986. Numerical study of intertidal zonation along Visakhapatnam coast, East coast of India. *Indian J. Mar. Sci.*, 15: 102-106.
- Narasimha Rao, G. M. and G. Subbarangaiah 1991. Control of spore shedding from some marine algae of the Visakhapatnam coast, India. *Br. Phycol. J.*, 26: 353-360.
- Narasimha Rao, G. M. and G. Subbarangaiah 2009. Spore shedding in some marine red algae of Indian Coast: A Review. *Adv. Pollen Spore Res.*, 27: 43-53.
- Narasimha Rao, G. M. and K. Prasanna Lakshmi 2009. Some numerical studies on marine algae of

- Viskhapatnam coast. *J. Algal Biomass Utiln.*, 1:60-85.
- Narasimha Rao, G. M. and G. Subbarangaiah 2010a. seasonal growth, spore shedding and life cycle of *Porphyra vietnamensis* Tanka et Ho. *Indian Hydrobiology*, 12(2):121-125.
- Narasimha Rao, G. M. and G. Subbarangaiah 2010b. Sporulation in marine brown algae of Indian coast: A review. *Adv. Pollen and Spore Res.*, 28:63-70.
- Narasimha Rao, G. M. and P. Pragaya Murthy 2012. Phytochemical analysis of *Lobophora variegata* (Lamouroux) Womersley ex Oliveira from Visakhapatnam coast. *Seaweed Res. Utiln.*, 34(1&2): 60-64.
- Narasimha Rao, G. M. and K. Prasanna Lakshmi 2014a. Effect of seaweed liquid fertilizer on seed germination and productivity of some vegetable crops. *Seaweed Res. Utiln.*, 36(1&2):78-83.
- Narasimha Rao, G. M. and Reshmi Chatterjee 2014b. Effect of seaweed liquid fertilizer from *Gracilaria textorii* and *Hypnea musciformis* on seed germination and productivity of some vegetable crops. *Universal J. Plant Sci.*, 2(7):115-120.
- Narasimha Rao, G. M., P. Pragaya Murthy and G. Subbarangaiah, 2012. Seasonal growth and spore shedding in *Rosenvingea nhatrangensis* Dawson from Bhimili, east coast of India. *Seaweed Res. Utiln.*, 34(1&2):22-26.
- Periyasamy, C. and P. V. Subba Rao 2015. Growth rate and carrageenan yield of cultivated *Kappaphycus alvarezii* (Doty) Doty in coastal waters of Bay of Bengal at Chelapa Timmapuram, Andhra Pradesh, East Coast of India. *J. Appl. Phycol.* (Communicated).
- Premila, V. E. and M. Umamaheswara Rao 1997. Effect of crude oil on the growth and reproduction of some benthic marine algae of Visakhapatnam coastline. *Indian J. Mar. Sci.*, 26:195-200.
- Premila, V. E. and M. Umamaheswara Rao 1998. Effect of refinery and fertilizer factory effluents on marine algae of Visakhapatnam coast. *Phykos*, 37: 41-49.
- Prasanna Lakshmi, K. 2009. *Some numerical studies on marine algae of Visakhapatnam coast*. M.Phil. Dissertation. Andhra University, Visakhapatnam, 57 p.
- Prasanna Lakshmi, K. and G. Mohan Narasimha Rao 2009. Some numerical studies on marine algae of Visakhapatnam coast. *J. Algal Biomass Utiln.*, 1(1): 60-85.
- Rama Rao, K. 2009. Potentiality of marine coastal ecosystem in Andhra Pradesh. In: *Proceedings of the International Conference of Algal Biomass, Resource and Utilization*. V. Krishnamurthy (ed), Krishnamurthy Institute of Algology, Chennai. pp. 18-20.
- Sarojini, Y. and N. S. Sarma 1999. Vitamin-C and content of macro algae of Visakhapatnam, east coast of India. *Indian J. Mar. Sci.*, 28:408-412.
- Sarojini, Y. and G. Subbarangaiah 1999. Seasonal variation in biochemical composition of some macro algae along Visakhapatnam, east coast of India. *Phykos*, 38:71-79.
- Saronini, Y. and K. Lakshminarayana 2009a. Mineral contents in some green seaweeds of Visakhapatnam coast. *Seaweed Res. Utiln.*, 31:145-150.
- Sarojini, Y. and K. Lakshminarayana 2009b. Effect of environmental factors on variations in distribution and photosynthetic pigments of macro algae of Visakhapatnam coast. *Seaweed Res. Utiln.*, 31: 127-134.
- Sarojini, Y. and K. Lakshminarayana, 2011a. Variations in the fatty acid composition of marine macro algae from Visakhapatnam coast. *Seaweed Res. Utiln.*, (1&2): 27-34.
- Sarojini, Y. and K. Lakshminarayana 2011b. Distribution of Vitamin-A content in some seaweeds of Visakhapatnam coast. *Seaweed Res. Utiln.*, 33(1&2): 35-37.
- Sarojini, Y. and K. Lakshminarayana 2011c. High performance liquid chromatographic distribution of Vitamin-D and E from seaweed of Visakhapatnam coast, Andhra Pradesh. *Seaweed Res. Utiln.*, 33(1&2):39-44.
- Sarojini, Y. and K. Lakshminarayana 2012. High performance liquid chromatographic of B-complex vitamins in some seaweeds of Visakhapatnam coast. *Seaweed Res. Utiln.*, 34(1&2):52-59.
- Sarojini, Y. and K. Lakshminarayana 2013. Seasonal variations and effect of temperature and salinity on the β -Carotene content of some seaweeds of Visakhapatnam, east coast of India. *Adv. Pollen Spore Res*, 31:143-149.
- Sarojini, Y. and K. Lakshminarayana 2014. Seasonal variations and effect of temperature on the β -Carotene contents of some seaweeds of Visakhapatnam, east coast of India. *Adv. Pollen Spore Res.*, 32:65-71.

- Sarojini, Y. and B. Sujatha 2014. Seaweed variations in distribution and biomass of five species of chlorophyceae at Visakhapatnam coast. *Seaweed Res. Utiln.*, 36(1&2):6-10.
- Sarojini, Y. and K. Uma Devi 2014. The marine macro algae as potential source of nutritionally important polyunsaturated fatty acid. *Der. Pharmacia Lettre*, 6(6):348-351.
- Sarojini, Y. and B. Sujatha 2015. The seasonal variations in distribution of photosynthesis pigments in two species of Phaeophyceae and the effects of light, dissolved oxygen and nutrients on their distribution. *Der Pharmacia Lettre*, 7(5):140-145.
- Sarojini, Y., K. Lakshminarayana and P. Seshagiri Rao 2012. Variation in distribution of flavonoids in some seaweeds of Viskhapatnam, east coast of India. *Der Pharma Chemica*, 4:1481-1484.
- Sarojini, Y., P. Santha Rao, B. Sujatha and K. Lakshminarayana 2013a. Distribution and diversity of marine macro algae in relation to environmental factors at Visakhapatnam coast. *Seaweed Res. Utiln.*, 35(1&2):54-64.
- Sarojini, Y., B. Sujatha and K. Lakshminarayana 2013b. Seasonal variation in distribution of macroalgal biomass in relation to environmental factors. *Int. J. Curr. Sci.*, 8E:21-27.
- Sarojini, Y., B. Sujatha and K. Lakshminarayana 2013c. Total phenol content and antioxidant activities of ethanolic extracts of two marine brown algae. *Int. J. Curr. Sci.*, 8E:43-49.
- Sarojini, Y., P. Neelima and B. Sujatha 2015. The seasonal variation in distribution of photosynthetic pigments in four edible species of chlorophyceae and the effect of light, dissolved oxygen and nutrients on their distribution. *Ann. Biol. Res.*, 6:36-40.
- Satya Rao, K., P. Prayaga Murty and G. M. Narasimha Rao 2011. Seasonal studies on marine algae of the Bhimili coast, East coast of India. *J. Algal Biomass Utiln.*, 2(2):69-82.
- Srinivasa Rao, A. 1988. *Ecological and callus induction experiments on Sargassum polycystum C. Agardh and laboratory growth studies on some intertidal algae*. Ph. D. Thesis, Andhra University. 218 p.
- Srinivasa Rao, A. and M. Umamaheswara Rao 1998. Effect of environmental factors of the growth of *Gracilaria corticata*, *Phykos*, 35:147-150.
- Srinivasa Rao, A. and M. Umamaheswara Rao 1999a. Effects of temperature, photon flux density and salinity on growth of *Sargassum polycystum* C. Agardh (Fuciales, Phaeophyta) under laboratory conditions. *Seaweed Res. Utiln.*, 21(1&2):35-40.
- Srinivasa Rao, A. and M. Umamaheswara Rao 1999b. Interaction of salinity and photonflux density on the growth of six marine algae. *Seaweed Res. Utiln.*, 21(1&2):41-48.
- Srinivasa Rao, A. and M. Umamaheswara Rao 2002. Seasonal growth pattern in *Sargassum polycystum* C. Agardh (Phaeophyta, Fuciales) occurring at Visakhapatnam, east coast of India. *Indian J. Mar. Sci.*, 31:26-32.
- Srinivasa Rao, A. and M. Umamaheswara Rao 2004. Seasonal variations in biochemical constituents of *Sargassum polycystum* (Phaeophyta, Fuciales) from Visakhapatnam, east coast of India. *Seaweed Res. Utiln.*, 26(Special Issue):201-204.
- Subbaramaiah, K. 2008. Whither *Gelidiella acerosa* production by cultivation and by natural propagation. *Seaweed Res. Utiln.*, 26(Special Issue):181-184.
- Subbarangaiah, G. 1978. *Studies on the some Gigartinales of the Visakhapatnam coast*. Ph.D. Thesis, Andhra Univeristy. 128 p.
- Subbarangaiah, G. 1983a. Seasonal growth, reproduction and spore shedding in *Gracilaria corticata* J. Ag. of the Visakhapatnam coast. *Proc. Ind. Natl. Sci. Acad.*, 6:711-718.
- Subbarangaiah, G. 1983b. Effect of environmental factors on germination and growth in *Hypnea valentiae* (Turn.)Mont. *All India Applied Phycological Congress*. 235-243.
- Subbarangaiah, G. 1984a. Growth reproduction and spore shedding in *Gracilaria textorii* (Sur.) J. Agardh of Visakhapatnam coast. *Phykos*, 23:246-253.
- Subbarangaiah, G. 1984b. Effects of environmental factors on germination and growth in *Gracilaria textorii*(Sur.). *J. Ag. Ind. J. Bot.*, 7(2):234-239.
- Subbarangaiah, G. 1985a. Spore shedding in *Gracilaria sjstedtii*(Kyllin) Dawson (Rhodophyta, Gigertinales). *Proc. All India Symp. Mar. Plants*, pp.59-64.
- Subbarangaiah, G. 1985b. Spore shedding in *Aglothamnion cordatum* (Boergesen) Feldmann Mezoyer (Rhodophyta, Ceramiales) of the Visakhapatnam coast. *Proc. Ind. Acad. Sci.*, (Plant

- Sci.) 95(2):121-127.
- Subbarangaiah, G. 1985c. Influence of temperature on the diurnal periodicity of tetraspore of some Gigartinales (Rhodophyta). *Seaweed Res. Utiln.*, 8(1&2): 23-27.
- Subbarangaiah, G. 1985d. Effects of environmental factors on germination and growth in *Gracilaria textorii* (Sur.) J. Ag. Ind. J. Bot., 7(2): 234-239.
- Subbarangaiah, G. 1986. Effects of environmental factors on the shedding of monospores from *Porphyra vietnemensis* Tanaka et Ho of the Visakhapatnam coast. *Phykos*, 25:29-35.
- Subbarangaiah, G. 1988. Carpospore and tetraspore germination and early stages of development in *Hypnea valentiae* (Turn.) Mont. *Ind. J. Bot.*, 11(1): 8-10.
- Subbarangaiah, G. 2005. Rhythms of spore shedding in algae. In: *Marine Plants Seaweed Research and Utilisation Association*. Madras. pp.17-24.
- Subbarangaiah, G., 2006. Advances in pollen-spore research: Rhythms of spore shedding in marine algae. *Adv. Pollen Res.*, 24: 27-42.
- Subbarangaiah, G. and E. Vanilla Kumari 1977b. Effects of environmental factors on spore shedding in *Jania rubens* (L) Lamouroux (Rhodophyceae, Cryptonemiales) of the Visakhapatnam coast. *National Symposium on Recent Trends in Algal Research*, Andhra University, Waltair.
- Subbarangaiah, G. and S. Sudhakar 1977. Diurnal periodicity in the shedding of spores in *Polysiphonia platycarpa* Boergeson (Rhodophyceae, Ceramiales) of the Visakhapatnam coast. G. Subbarangaiah (ed). *Recent Trends in Algal Research*. pp.270-282.
- Subbarangaiah, G. and M. U. Rao 1983. Seasonal growth, reproduction and spore shedding in *Hypnea valentiae* (Turn.) Mont. *Proc. Ind. Acad. Sci. (Plant Sci.)* 92: 473-482.
- Subbarangaiah, G., and E. Vanilla Kumari 1997. Seasonal growth reproduction and spore shedding in *Amphiroa fragilissima* (L) Lamouroux (Rhodophyceae, Cryptonemiales) of the Visakhapatnam Coast. G. Subbarangaiah (ed). *Recent Trends in Algal Research*. pp.255-269.
- Subbarangaiah, G. and D. Appa Rao 2004. Growth, reproduction and oospore shedding in *Sargassum vulgare* of Visakhapatnam coast. *Indian Hydrobiology*, 6:7-12.
- Subbarangaiah, G., M. U. Rao and B. G. S. Rao 1975. Effect of salinity of spore shedding in *Gracilaria corticata*. *Curr. Sci.*, 44:717-718.
- Subbarangaiah, G., S. Sudhakar and E. Vanilla Kumari 2002. Seasonal growth, reproduction and spore liberation in *Wrangelia argus* Mont. (Ceramiales, Rhodophyta) of Visakhapatnam coast. *Phykos*, 41(1&2):121-123.
- Subbarangaiah, G., S. Sudhakar and E. Vanilla Kumari 2003a. Seasonal growth, phenology and spore shedding in *Polysiphonia platycarpa* Boergeson (Ceramiales, Rhodophyta) of Visakhapatnam coast. *Algae*, The Korean Society of Phycology, 18(2): 177-181.
- Subbarangaiah, G., S. Sudhakar and E. Vanilla Kumari 2003c. Seasonal growth, phenology and spore shedding in *Centroceras clavulatum* (C. Ag.) Mont. (Ceramiales, Rhodophyta) of Visakhapatnam coast. *J. Aqua. Biol.*, 18(1):1-7.
- Subbarangaiah, G., G. M. Narasimha Rao and D. Deepthi Lavanya 2012a. Effect of environmental factors on oospore shedding in *Sargassum ilicifolium* C. Agardh. *J. Algal Biomass Utiln.*, 3(2):57-64.
- Subbarangaiah, G., G. M. Narasimha Rao and D. Deepthi Lavanya, 2012b. Effect of environmental factors on oospore shedding in *Gracilaria corticata* J. Agardh. *Plant Sci. Res.*, 34(1&2):43-46.
- Subba Rao, P. V. and M. Ganesan 2006. Field cultivation of *Gelidiella acerosa* in India. In: *Recent advances on applied aspects of Indian Marine algae with reference to global scenario*. Vol. 1. T. Aewari (ed), CSMCRI, Bhavunagar. pp.296-309.
- Subba Rao, P.V., K. Rama Rao, M.R.P. Nair and K. Subbarangaiah 1983. A systematic list of marine algae from Andhra Pradesh and their distribution. In: *Marine Plants. Seaweed Research and Utilisation Association*. Madras. pp.29-34.
- Subba Rao, P.V., K. Eswaran and M. Ganesan 2004. Cultivation of agarophytes in India: retrospect, prospects and future strategies. *Seaweed Res. Utiln.*, 26(Special Issue):181-184.
- Sudhakar, G. and G. Subbarangaiah 1993. 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. pp.26-28.
- Umamaheswara Rao, M. 1964. *The ecological study of intertidal algae of Visakhapatnam coast*. Ph.D., Thesis, Andhra University.
- Umamaheswara Rao, M. 1978. Seaweed resources of Andhra Pradesh. *Seaweed Res. Utiln.*, 3(1&2):51-55.
- Umamaheswara Rao, M. 1987. Growth, reproduction and spore shedding in *Grateloupia filicina* (Wulfen) C. Agardh. *Seaweed Res. Utiln.*, 10(1&2):33-38.
- Umamaheswara Rao, M. 1990. Autoecological and ecophysiological studies on marine algae of Visakhapatnam and Mandapam coast. In : *Perspectives in phycology* (M.O.P. Iyengar Centenary Celebration). U. N. Raja Rao (ed). pp.323-335.
- Umamaheswara Rao, M. 1995. *Final report of the Department of Biotechnology of the Laboratory culture and Biotechnology of two useful seaweeds*.
- Umamaheswara Rao, M. 2011. Diversity and commercial feasibility of marine macroalgae of India. *Seaweed Res. Utiln.*, 33(1&2):1-13.
- Umamaheswara Rao, M. and T. Sreeramulu 1963. Vertical zonation and seasonal variation in the growth of *Porphyra* of Visakhapatnam coast. *Curr. Sci.*, 32: 173-174.
- Umamaheswara Rao, M. and T. Sreeramulu 1964. An ecological study of intertidal algae of Visakhapatnam coast. *J. Ecol.*, 52:595-616.
- Umamaheswara Rao, M. and T. Sreeramulu 1968. Recolonization of algae on denuded rocky surfaces of Visakhapatnam coast. *Bot. Mar.*, 11:122-126.
- Umamaheswara Rao, M. and T. Sreeramulu 1970a. An annotated list of the marine algae of Visakhapatnam (India). *Bot. J. Linn. Soc.*, 63:23-45.
- Umamaheswara Rao, M. and T. Sreeramulu 1970b. The fruiting behavior of some marine algae of Visakhapatnam coast. *Bot. Mar.*, 13(1):47-49.
- Umamaheswara Rao, M. and T. Sreeramulu 1974. Observation on changes in the growth of four intertidal algae at Visakhapatnam. *Bot. Mar.*, 17:52-54.
- Umamaheswara Rao, M. and N. Kaliaperumal 1980. Genus *Pterocladia* (Rhodophyceae) from India. *Bull. Bot. Surv. India*, 22(1-4):109-111.
- Umamaheswara Rao, M. and G. Subbarangaiah, 1981. Effect of environmental factors on the diurnal periodicity of tetraspores of spore Gigartinales, Rhodophyta. *10th Intl. Seaweed Symp.*, Sweden. pp. 208-214.
- Umamaheswara Rao, M. and R. B. Sanjeeva Reddy 1982. Influence of desiccation, salinity and temperature on the liberation and germination of tetraspores of *Dictyota dichotoma*. *Seaweed Res. Utiln.*, 10(1&2): 33-38.
- Umamaheswara Rao, M. and G. Subbarangaiah, 1988. Effects of environmental factors on the shedding of tetraspores of some Gigartinales (Rhodophyta). *Proc. Symp. Coastal Aquaculture*, 4:119-1205.
- Umamaheswara Rao, M. and N. Kaliaperumal, 1983. Effects of environmental factors on the liberation of spores from some red algae of Visakhapatnam coast. *J. Exp. Mar. Biol. Ecol.*, 70(1): 45-53.
- Umamaheswara Rao, M. and N. Kaliaperumal 1987a. Diurnal periodicity of spore shedding in some red algae of Visakhapatnam coast. *J. Exp. Mar. Biol. Ecol.*, 106: 193-199.
- Umamaheswara Rao, M. and N. Kaliaperumal 1987b. Effect of thermal stress on spore shedding in some red algae of Visakhapatnam coast. *Indian J. Mar. Sci.*, 16: 201-202.
- Umamaheswara Rao, M. and G. Subbarangaiah 1988. Effect of environmental factors on the shedding of tetraspores of some Gigartinales (Rhodophyta). *Proc. Symp. Coastal Aquaculture*, 4:1199-1205.
- Umamaheswara Rao, M. and A. Srinivasa Rao 1996. Callus formation in *Sargassum polycystum*. *Phykos*, 35:147-150.
- Umamaheswara Rao, M. and S.B.K. Murthy 2011. Effect of industrial effluents in photosynthesis and respiration of macroalgae of Visakhapatnam coast. *Seaweed Res. Utiln.*, 33(1&2):45:45-52.