2. REVIEW OF LITERATURE

Seaweeds are marine macrophytes belong to non-flowering groups and adapted to inhabit marine ecosystem. These autotrophic plants are commonly found in intertidal as well as in the subtidal regions of the sea. Based on morphology, cellwall and pigment composition, seaweeds are classified into green (Chlorophyceae), red (Rhodophyceae) and brown (Phaeophyceae) seaweeds (Chapman, 1970). In India certain coastal pockets of the peninsular coast comprising nine maritime states and in the Andaman -Nicobar as well as the Laccadive archipelago harbour dense beds of seaweeds that can be exploited for commercial purposes. In the following pages the available literature from the print as well as the e-media relevant to the topic of research were reviewed under the following heads.

2.1 Seaweed utilization

The redalgae such as *Gracilaria, Gelidiella, Gelidium* and *Pterocladia* yield Agar (agar-agar). Some other red algae viz., *Kappaphycus, Hypnea, Gigartina* and *Chondrus* are the major source for the production of Carrageenan. Algin (alginic acid) is also obtained from brown algae like *Sargassum, Hormophysa, Laminaria, Turbinaria, Undaria, Cystoseria* and *Macrocystis* (Anon.,1987). These phycocolloids are used as gelling, stabilizing and thickening agents in food, confectionery, pharmaceuticals, dairy, textile, paper and paint industries. Apart from these, products such as mannitol, Iodine, Laminarin and Fucoidin are also obtained from seaweeds. Many protein rich seaweeds such as *Ulva, Enteromorpha, Caulerpa, Codium, Monostroma, Sargassum, Hydroclathrus, Laminaria, Acanthphora* are used as human food (Anon., 1987). In Japan, Korea, China, Malaysia, Philippines and other Southeast Asian countries seaweeds are used in the form of soup, salad and vegetables. The food value of seaweeds depends on their protein, minerals and vitamins present in them (SEAFDEC., 2000).

Seaweeds such as *Enteromorpha linza, Enteromorpha prolifera, Ulva fasciata, Caulerpa taxifolia* and *Sargassum johnstonii* from natural and cultivated populations were evaluated for food safety and nutritional quality (Naidu *et al*., 1993) and they found that acute oral feeding of *E. linza, U. fasciata, C. taxifolia* and *S. johnstonii* and subacute oral feeding of *E. linza* for 12 weeks did not produce any toxic effects on male and female rats. Secondary metabolites of seaweed *Ulva fasciata* and *Hypnea musciformis*,collected form southeast and southwest coast of India were tested for biotoxicity potential and both these species showed potential antibacterial activity, brine shrimp cytotoxicity, larvicidal, antifouling activities (Selvin and Lipton, 2004). Nutritional value of six species of seaweeds (*Sargassum wightii, Ulva lactuca, Kappaphycus alvarezii,* *Hypnea musciformis, Acanthophora spicifera* and *Gracilaria corticata*) as complementary source of dietary proteins for animal nutrition was evaluated based on their amino acid profile (Vinojkumar and Kaladharan, 2007).

Dry biomass of *Sargassum wightii* exhibited maximum metal uptake at pH 4–5 and the value ranged from 18% to 29% of dry biomass and the kinetics of metal adsorption was fast with 70–80% taking place within 30 min. Based on these results, a biobattery involving perforated columns packed with pulverized dry biomass of S. wightii was designed, which could remove metals in the range of 50–97% from a multi-metal ion solution within two and a half hours (Vinojkumar and Kaladharan, 2006).

Net primary production (NPP) of 10 commonly available seaweeds of Minicoy atoll varied from 2 to 10 g C/m^3/day. The mean of NPP of these 10 seaweeds when measured individually was 5.68 g C/m^3/d and that of all seaweeds incubated collectively registered 5.32 g C/m^3/d. Hence they presumed that the probable rate of NPP of seaweed community contributing to Minicoy lagoon to be approximately 5g/C/m3/d (Kaladharan and Kandan, 1997). Polyculture practice of *Gracilaria* and shrimp improve water quality to great extent and prevent bacterial diseases of shrimp (Liu *et al*., 1997). Cultivation of *Gracilaria parvispora* in shrimp farm effluents enhanced the growth of the algae (Nelson *et al.*, 2001).

Seaweeds are utilized in different parts of the world in diversified fields such as animal feed, fertilizer for crops etc (Deve *et al*., 1977). The high amount of water soluble potash, other minerals and trace elements present in seaweeds are readily absorbed by plants and they check deficiency diseases in crops. Liquid seaweed products were introduced in 1950 and now enjoy a world-wide reputation. The manure value of these products is not related to their NPK. content and they show unusual properties such as enhanced germination of seeds, increased frost resistance and they induce resistance to fungal and insect pests (Booth, 1969).

Cytokinin like substances were extracted from green seaweed, *Caulerpa racemosa* and purified using an ion exchange column of CM-cellulose. Bioassay of these extracts with dark-germinated cotyledons of cucumber for chlorophyll biosynthesis proved the presence of cytokinin a plant growth promoter in the extract of *C. racemosa* whose efficiency was comparable to that of commercially available kinetin (Kaladharan and Sridhar, 1999).

Cost effective and organic medium for the laboratory culture of microalgae has been developed from the extracts of some selected green seaweeds (Kaladharan *et al*., 2002). Agar factory waste was tried as fuel for cooking and manure for seedlings of cowpea (*Vigna ungiculata*,L) which registered improved seedling vigour. As fuel cakes prepared out of agar factory waste registered high energy content, high ash content and high rate of combustibility over fire wood (Kunda and Kaladharan, 2003).

Jothinayagi and Anbazhagan (2009) studied the effect of different concentrations (20%, 40% 60%, 80% and 100%) of seaweed liquid fertilizer (SLF) of *Sargassum wightii* on the growth and biochemical characteristics of *Abelmoschus esculentus*. Sridhar and Rengasamy (2010) tested the efficiency of different concentrations of Seaweed Liquid Fertilizers (SLFs) obtained from the brown seaweed *Sargassum wightii* and green seaweed *Ulva lactuca* on groundnut *Arachis hypogaea* under field trial. Thirumaran *et al* (2009) attempted to investigate the effect of Seaweed Liquid Fertilizer of *Rosenvigea intricata* with or without chemical fertilizer on seed germination, growth, yield, pigment content and soil profile of *Abelmoschus esculentus.*

Erulan *et al* (2009) investigated the effect of seaweed liquid fertilizer of *Sargassum polycystum* on the seed germination growth, yield, biochemical and pigment characteristics of pigeon pea, *Cajanus cajan*. The effect of different concentrations of liquid seaweed fertilizer of *Ulva lactuca* on morphological and biochemical changes of *Vigna unguiculata L.* was assessed by Lakshmi and Sundaramoorthy (2010). The seaweed liquid fertilizer derived from the green seaweed *Ulva lactuca* was used to study its effect on physical and biochemical parameters and yield of *Capsicum annum* (Sridhar and Rengasamy, 2012).

2.2 Seaweed distribution and their Resource Assessment

More than 10,000 species of marine algae have been reported from all over the world. Total world production of seaweeds is estimated to 6-7 million tonnes, of which nearly 90% comes from Asia-Pacific region (Hurtado- Ponce, 1996). According to FAO data base (1998) out of the 7 million tonnes of seaweeds, 4 million tonnes are brown seaweeds, 1.9 million tonnes are red seaweeds and the rest of them are green seaweeds. In India luxuriant growth of several species of seaweeds occur along the South east coast of Tamilnadu, Gujarat, Lakshadweep (Laccadives) and Andaman-Nicobar Islands. Fairly rich seaweed beds occur in the vicinity of Mumbai, Ratnagiri, Goa, Karwar, Bhatkal, Quilon, Varkala, Vizhinjam, and Visakhapatnam as well as in coastal lakes such as Chilka and Pulikat (Umamaheswra Rao, 1969; Chennubhotla, 1996; Kaliaperumal, 1993). Indian coastline is endowed with 844 species of marine algae comprising 216 species of chlorophyta, 191 species of Phaeophyta, 434 speceis of Rhodophyta and 3 species of Xanthophyta (Oza and Zaidi, 2001).

Thivy (1951) estimated about 3,000 tonnes of fresh agarophytes per annum from Indian waters excluding the resources of Laccadive and Andaman Islands, while her estimate in 1960 (Thivy, 1960) indicated about 35 metric tonnes of dry agarophytes per annum from Indian waters and Chacko and Malu Pillai (1968) estimated 6,000 tonnes of agarophytes and 60,000 tonnes of brown algae for the area between Point Calimere and Cape Comorin. Varma and Rao (1962) surveyed Pamban area of Mandapam coast during 1961- 62 covering an area of 234.25 sq. km along the Hare Island on the west and Shingle Island on the east and estimated a standing crop of 70754 tonnes of agarophytes and 131588 tonnes of alginophytes from which 341.35 tonnes wet weight of agarophytes and 657.94 tonnes wet weight of alginophytes can be harvested.

From the seaweed resources surveys carried out in the intertidal and shallow water areas of east and west coasts and also the archipelago of Laccadives and Andamans so far by the CMFRI Cochin, CSMCRI Bhavnagar and NIO Goa, it could be estimated that total standing crop of all the seaweeds in Indian waters is more than 100,000 tonnes (wet weight) consisting of 6000 tonnes of agar yielding red seaweeds, 16000 tonnes of algin yielding brown seaweeds and the remaining quantity of edible and other seaweeds(Devaraj *et al*., 1997).

Chennubhotla *et al*. (1987) made a review on the biological aspects of economically important Indian seaweeds which include the taxonomy and ecological studies at different localities along the Indian coast, growth pattern, period of maximum growth, fruiting seasons for species such as *Cystoseira indica*, *Sargassum, Turbinaria, Gracilaria verrucosa* and *Gelidiella acerosa*. Chennubhotla *et al*.(1988) conducted an extensive resource assessment survey along the Kerala coast and brought out the details of availability of commercially important resources for the first time. Occurrence of *Porphyra kanyakumariensis* was reported from the southern Kerala coast by Chennubhotla *et al* (1990). *Gracilariopsis lemaneiformis*, a long thalloid agar yielding red alga has been reported from certain backwaters of Dhalawapuram, (Quilon), Kadalundi (Kozhikode) and Mopla Bay (Kannur) along the Kerala coast (Kaladharan, 2005).

Stock of *Gracilaria edulis* was introduced in the Lagoon of Minicoy Atoll from Kavarathi Isaland (Laccadives) and Rameswaram coast (Gulf of Mannar) in the year 1990. Until then this resource was not reported from Minicoy Atoll (Kaladharan and Chennubhotla,1993). Kalimuthu and Kaliaperumal(1991) reported the unusual landing of a long thalloid agar yielding variety of *Gracilaria edulis* in Kottaipattinam area of Tamilnadu coast which they considered drifted from Srilankan waters. Kaladharan (2001) reviewed the seaweed resource assessment surveys carried out by

CMFRI, CSMCRI and NIO in the Lakshadweep Islands and indicated nearly 10,000- 19000 tonnes wet weight of standing crop of seaweeds in 12 atolls of Laccadive archipelago comprising 114 species belonging to 62 genera. Seaweed distribution and resource assessment from 15 localities along the Kerala coast was studied by Kaliaperumal and Chennubhotla (1997) and they reported 35 species belonging to 25 genera and 18 families.

Studies on the distribution and seasonal changes in the marine algal flora of Rameswaram coast was made for a period of one year from July 1983 to June '84 by fortnightly collection of algae from intertidal and subtidal regions upto 1.0 m depth at seven localities namely Rameswaram, Pamban, Krusadi Island, Thonithurai, Seeniappa Darga, Pudumadam and Kilakarai. Out of 104 algal species, Kurusadi Island registered a maximum number of 77 algal species and Rameswaram recorded a minimum number of 35 species (Kalimuthu *et al*., 1992). Umamaheswara Rao *et al* (2009) studied the morphological and anatomical characters of two varieties of *Gracilaria tenuistipitata*, namely var. *tenuistipitata* Chang et Xia and var. liui Zhang et Xia and an unidentified *Gracilaria* species, occurring in the Chilka Lake.

Nettar and Panikkar (2009) described two new species from the Family Ralfsiaceae, *Hapalospongidion thirumullavaramensis* and *Pseudolithoderma thangass*eriensis, collected from the Quilon coast of Kerala. The taxonomy of four species of *Feldmannia* collected from different parts of Kerala such as *F. collumellaris*, *F. irregularis* and two new species: *F. sahnienii* and *F. renienii* was also reported by Nettar and Panikkar (2009 a). Nettar and Panikkar (2009b) reported five species of *Hincksia* collected from different parts of Kerala and these include, *H.clavata* (Krishnamurthy and Baluswami) Silva, *H. rallsiae* (Vickers) Silva, *H. sandriana* (Zanardini) Silva, *H. mitchelliae* (Harvey) Silva and *H. turbinariae* (Jaasund) Silva. Among these, *H. rallsiae* is a new report to the Indian marine flora. Nettar (2009) described with illustrations the occurrence of *Hecatonema*: *H. sargassicola* Boergesen and *H. terminale* (Kuetzing) Kylin, collected from Kerala and Tamil Nadu.

Palanisamy (2009) reported *Avrainvillea amadelpha* (Montagne) A.Gepp & E.Gepp. for the first time from Mahatma Gandhi Marine National Park, Andamans. Balakrishnan *et al* (2009) conducted a general survey for agarophytes in the Gulf of Mannar and found that the agarophytes recorded in all the five stations in the Gulf of Mannar, South east Coast of India were three species of *Gracilaria*, *Gelidiella acerosa* and *Gelidium pusillum*. Balakrishnan (2009a) while on his resource assessment survey carried along the Gulf of

Mannar observed that *Hypnea musciformis* and *H. valentiae* occurred in all the five stations during the survey for carrageenophytes in the Gulf of Mannar region. The alginophytes recorded at all the five study sites were *Padina tetrastromatica*, three species of *Sargassum*, *Stoechospermum marginatum*, three species of *Turbinaria* and two species of *Dictyota* (Balakrishnan, 2009b).

2.3 Exploitation from natural bed

Effect of repeated harvesting on the growth of commercially important seaweeds such as agar yielding *Gelidiella acerosa* and *Gracilaria corticata* and algin yielding seaweeds *Sargassum cristaefollium*, *S. ilicifolium*, *S. myriocystum, S. wightii* and *Turbinaria conoides* growing in Krusadai Island, Pudumadam and Kilakkarai area was investigated by Kaliaperumal *et al*. (1990; 1996) and by Kalimuthu *et al*., (1993) for two years and from Kerala coast for one year period by Ushakiran and Kaladharan (2011). Ugarte *et al*.(2006) observed the changes in the morphology and biomass production in *Ascophyllum nodosum* due to harvesting by rake cutter from southern New Brunswick.

Data collected on the commercial exploitation of seaweeds from the natural seaweed beds of Tamilnadu during 4 years period from 2000 to 2003 (Kaliaperumal *et al*., 2004) showed that the quantity of agarophytes viz. *Gelidiella acerosa*, *Gracilaria edulis, G.crassa, G.foliifera* and *G.verrucosa* varied from 965 to 1518 tonnes (dry wt) and alginophytes, *Sargassum* spp and *Turbinaria* spp from 1433 to 2285 tonnes (dry wt) per year. They have recommended that commercial harvest of seaweeds in Gulf of Mannar and Palk Bay only during the peak growth period of the algae from August to January.

2.4 Proximate composition

Biochemical composition of some marine algae from Mandapam coast, Tamil Nadu was assessed by Chennubhotla *et al*.(1977). Protein, lipid and carbohydrate content of the red algal species *Porphyra kanyakumariensis* reported from the southern Kerala coast was studied by Chennubhotla *et al* (1990). Christabel *et al*.(2011) screened aqueous extracts of seven species of marine macroalgae for their antimicrobial activity against ten pathogenic bacterial strains. Seasonal variation in growth and biochemical constituents such as protein, carbohydrate and lipid in *Hypnea valentiae, Acanthophora spicifera, Laurencia papillosa, Enteromorpha compressa, Ulva lactuca* and *Caulerpa recemosa* from Mandapam coast were observed for one year from April, 1995 to March 1996 (Kaliaperumal *et al*., 2002). Kaladharan and Velayudhan (2005) tested the crude GABA (γ- amino butyric acid) extracted from *Hypnea valentiae* collected from Vizhinjam coast and compared its activity of favouring settlement of pediveliger larvae of green mussel *Perna viridis* with that of standard commercial grade GABA.

2.5 Effect of environmental factors

Experiments were conducted with tetrasporophytes of *Gelidium pusillum*, *Pterocladia heteroplatos*, and *Gelidiopsis variabilis* to determine the effects of various environmental factors on the liberation of spores at Visakhapatnam coast (Umamaheswara Rao and Kaliaperumal, 1983). They observed that the ability to liberate spores and the quantity of spores shed by these three red algae varied with submerged condition of the plants, photoperiod, irradiance, salinity and temperature. Kaliaperumal (1989) investigated the effects of desiccation, salinity, light, DO and temperature on the diurnal periodicity in liberation of tetraspores of *Gelidium pusillum*, *Pterocladia heteroplatos* and *Gelidiopsis variabilis*.

Effect of light intensity, epiphytes and grazing on the growth of *Gracilaria edulis* cultivated in Palk Bay and Gulf of Mannar near Mandapam was studied by Kaliaperumal *et al* (1993) and they suggested ideal period of cultivation of *G. edulis* in Gulf of Mannar to be during November to March. Kaladharan *et al*. (1996) have attempted to optimize certain physical and biological parameters associated with cultivation of *Gracilaria edulis* in Island ecosystem such as effect of planting density, depth of water above substratum, periodic cleaning for removal of epiphytes, grazing pressure and regeneration after successive harvest from Minicoy Atoll of Laccadives.

Studies on the salinity tolerance of 13 economically important seaweeds were attempted from Mandapam coast (Kaliaperumal *et al*., 2001). Effect of thermal stress (10 - 45 °C) on the liberation of tetraspore from *Gelidium pusillum, Pterocladia heteroplatos* and *Gelidiopsis variabilis* was monitored in response to various temperature (Kaliaperumal and Umamaheswara Rao, 1987). Gulshad *et al*. (1999) studied the impact of domestic waste discharge on the *Caulerpa racemosa* collected from a densely populated village of Minicoy Island. Rate of spore shedding and spore output in the tetrasporophytes of *Gelidium pusillum, Pterocladia* and *Gelidiopsis* were found to vary considerably with the salinity, temperature and photoperiod (Umamahswara Rao and Kaliaperumal, 1983). The quality of agar and carrageenan is usually determined by their gel-strength and that of algin is by its viscosity. Durairatnam (1987) pointed out that agar yield and gel-strength varies seasonally. Luhan (1992) observed distinct changes in agar yield and gel-strength coinciding with the changes in environmental conditions. There is a clear seasonality in the yield of agar from *Champia nova* with lower values in winter and higher values in spring

(Miller *et al*., 1996). Calumpong *et al*., (1999) observed a strong correlation between agar yield and nutrient levels in ambient water. Fereile -Pelegrin *et al*.(1999) found correlation between agar yield and seasonal changes.

2.6 Seaweed culture

Kaliaperumal *et al* (1986) conducted experimental field cultivation of *Acanthophora spicifera* following vegetative propagation method in the Gulf of Mannar. Reeta and Kaliaperumal(1991) successfully conducted experimental culture of *Gracilaria edulis* by spore shedding method at Mandapam on cement blocks during November 1988- April 89. Grazing incidence of cultured seaweed *Gracilaria edulis* in Minicoy lagoon is well documented (Chennubhotla *et al*.,1994). The experimental culture of *Gracilaria edulis* by spore shedding method was carried out at Mandapam on cement blocks from November to April, 1989 (Reeta and Kaliaperumal, 1991). According to them the spores grew to adult plants reaching a maximum length of 16 cm after four months of their output Reeta and Ramamoorthy (1999) reported the *s*easonal variation in the growth of *Gracilaria edulis* cultured from spores through an year long experiment conducted in *G.* in the Gulf of Mannar and Palk Bay, near Mandapam, along the southeast coast of India.

With a view to find out the feasibility of Lakshadweep lagoons for cultivation of *Gracilaria edulis*, experimental culture was undertaken at four sites in Minicoy lagoon (Chennubhotla *et al*., 1992) and encouraging results were obtained indicating high potential of about 8.1 fold increase for this species in the lagoon environment of Minicoy. Kaladharan *et a*l (1996) conducted mariculture of the agar-yielding red seaweed, *Gracilaria edulis* in Minicoy lagoon during 1990–1992. Experiments were conducted on dry matter accumulation, effects of planting density, depth of water above culture nets, periodic cleaning for removal of epiphytes, grazing and the yield as well as regeneration of *G. edulis* after successive harvests to understand the optimum requirements of this seaweed. Artificial seawater prepared with simplified receipes was found suitable for maintaining seaweeds of commercial importance under laboratory conditions (Kaladharan, 2000). In India, cultivation of carragennophyte *Kappaphycus alvareizii* started in Diu of Sourashtra coast and in Mandapam on the south-east coast of India, during 1995–1997 for carrageenan production (Mairh *et al*., 1995; Mishra *et* al., 2006; Johnson and Gopakumar, 2011). The current status of *Kappaphycus* farming and the constraints are reviewed by Johnson and Gopakumar (2011).

2.7 Seaweed industry

The seaweed industry in India is mainly a cottage industry and is based only on natural stock of agar yielding red seaweeds such as *Gelidiella acerosa* and *Gracilaria edulis* and Algin yielding brown seaweeds such as *Sargassum* and *Turbinaria*(Coppen,1991; Kaladharan and Kaliaperumal, 1999). Kaladharan and Kaliaperumal (1999) reported that India produces 110-132 tonnes of dry agar annually utilizing about 880-1100 t of dry agarophytes and 360-540 tonnes of algin from 3600-5400 tonnes of dry alginophytes with the help of nearly 40 seaweed processing units of which 22 produce agar. Carrageenan production in India started very recently with the beginning of large scale cultivation of *Kappaphycus alvarezii* in the Palk Bay (Johnson and Gopakumar, 2011).

Agar producers in India follow a simple method of agar extraction (Armisen and Galatas, 1987). In this method they boil the dry weed, the hot extract is filtered, cooled, freeze thawed, bleached and dried in the sun. The agar is marketed either in strips or as powder. *Gelidiella acerosa* yields industrial grade agar, where as species of *Gracilaria* yield food grade agar (Coppen,1991; Kaladharan and Kaliaperumal,1999). *Sargassum and Turbinaria* are the two major raw material used in Algin industry in India. *Sargassum* is preferred over *Turbinaria* as the quality and quantity of algin yield are better from the former (Coppen, 1991). Most of the algin producing units in India are capable of producing 20-30 tonnes /year and total algin production in India is 360-540 tonnes /year (Kaladharan and Kaliaperumal, 1999). World production of carrageenan has shown a 4% annual growth from 1978 to 1993 and the five leading market for carrageenan are Europe-36%, North America-26%, Latin America-17%, Australia 13% and Japan-8% (Hurtado-Ponce, 1996).

Kaliaperumal *et al* (2004) analysed the data on commercial exploitation of seaweeds from the natural seaweed beds of Tamilnadu coast for four years from 2000- 2003 and they recommended the harvest of seaweed from the natural beds during the peak growth period commencing from July to January. It is estimated that 90% of dry biomass of raw material used for the extraction of agar is considered as waste as the available method can extract only 10-12 % agar from the raw material. The agar factory discharge has been utilized as fuel for cooking and manure for field crops effectively (Kunda and Kaladharan, 2003).

2.8 Seaweeds and Phycocolloids

Phycocolloids refer to those polysaccharides extracted from both fresh water and marine algae (Armisen and Galatas,1987). Polysaccharides derived from marine red and brown algae such as agar, carrageenan and algin are economically important and have commercial significance, since these polysaccharides exhibit high molecular weight, high viscosity and excellent gelling, stabilizing and emulsifying properties (Ji Minghou, 1990). These colloids have many applications in food, pharmaceutical, cosmetic, biotechnologic industries etc as gelling agents, thickeners or stabilizing and emulsifying agents (Yaphe, 1984; Anon., 1987; Kaladharan *et al*., 1998).

The basic structure of agar is a regularly alternating sequence of 3 -linked-β D galactopyranose and 4 - linked 3 -6 anhydro -α- L- galactopyranose. Carrageenan which is also derived from different genera of Rhodophyta (red seaweeds) is a linear polysaccharide with a repeating structure of alternating 1, 3-linked- β- D galactopyranose and 1-4 linked α- D- galactopyranose units. The 3 linked units occur as the 2-and 4-sulphate or unsulfated, while the 4-linked units occur as the 2-sulphate, 2,6- disulphate, the 3,6 anhydridand the 3,6 anhydrid 2- sulphate (Stanley, 1987). Algin (also known as alginate or alginicacid) extracted from genera of Phaeophyta (brown seaweeds) is a linear polymer based on two monomeric units, β- D mannuronic acid and α- L-guluronic acid (Wilma, 1990).

Varma and Rao (1962) estimated that 11.84 tonnes of dry algin can be extracted from 98.69 tonnes of dry alginophytes and 5.59 tonnes of dry agar from 36.38 toones of dry agarophytes from the Pamban area of Mandapam coast. Studies were made on the yield and physical properties of agar from *Gelidiella acerosa*, *Gracilaria arcuata* and *G. edulis* and algin and mannitol from *Padina boergesenii*, *Chnoospra implexa*, *Sargassum duplicatum*, *Turbinaria conoides* and *T. ornata* growing in eight islands of Lakshadweep (Kaliaperumal *et al*., 1989) . Kaliaperumal *et al.* (1990a) have extracted agar from eight red algae and algin from 10 brown algae collected along south Tamilnadu Coast.

2.8.1 Agar

It was during the second World War, due to the shortage of agar, that the Board of Scientific and Industrial Research started manufacture of agar in India at the Research Department of Kerala University. Since then, much stride has been made in these lines on the economic utilization of algae and the Central Marine Fisheries Research Institute developed a cottage industry method for the manufacture of agar from *Gracilaria* spp. and *Gelidium micropterum* (Thivy,1960). The agar obtained from *Gracilaria verrucosa* growing in Chilka Lake, Odisha was studied qualitatively and quantitatively and recommended using different agarophyte species like *Gelidlella acerosa* and *Gracilaria edulis* in three different proportions to obtain desired quality of gel by Chennubhotla *et al* (1977).

Istini *et al*., (1994) compared the yield and physical properties of agar after alkali treatment at different temperatures from *Gracilaria chorda* from Japan, *G. fisheri* from Thailand and *G. lemaneiformis* from Chile. Optimum levels of alkali/ acid treatment and thermal manipulations during extraction of agar were determined to increase the yield and quality of agar from *Gracilaria edulis* (Rao and Kaladharan, 2003).

Results obtained on seasonal growth, yield and physical properties of agar in *Gelidiella acerosa* and *Gracilaria edulis* for one year is presented by Chennubhotla and his team from Rameswaram coast (Chennubhotla *et al*., 1986). Seventeen agar samples were extracted from *Gelidiella acerosa* (Forsskal) Feldmann and Hamel (Rhodophyta, Gelidiales) specimens collected from nine different sites on the Indian coast- five from southeast coast and four from the west coast for stability characteristic of their gels (Prasad *et al*, 2007). They have evaluated the stability characteristics of gels from 17 agar samples extracted from *Gelidiella acerosa* collected from five sites along the Southeast coast and four sites along the West coast of India.

Balakrishnan *et al.*(2009) reported that among the agarophytes, three species of *Gracilaria, Gelidiella acerosa* and *Gelidium pusillum* found in the Gulf of Mannar, *Gracilaria edulis, Gelidiella acerosa* and *Gelidium pusillum* showed a yield of agar above 60% from many of the study sites which exceeded the values reported earlier.

2.8.2 Alginic acid

Kaliaperumal and Kalimuthu (1976) studied the seasonal changes in growth, reproduction and the content of alginic acid and mannitol in *Turbinaria deccurens* from Rameswaram coast. Chennubhotla *et a*l (1982) found that alginic acid yield varies with the seasonal growth behaviour of *Sargassum ilicifolium* and *S. myriocystum* showing maximum yield in July to August and recommended the suitable harvesting period for getting the maximum yield of alginic acid between July and September. Variation in growth and manitol content in *Padina gymnospora* conducted during 1975- 76 was reported by Chennubhotla *et al*.(1977a).

Studies were made from September 1985 to August 1986 on the standing crop, algin and mannitol contents of three brown algae, *Colpomenia sinuosa, Hydroclathrus clathratus* and *Rosenvingea intricata* growing at Shingle Island and Kilakarai near Mandapam and there was no marked seasonal variation in the yield of algin and mannitol in these algae (Kalimuthu *et al*., 1991). Kalimuthu *et al*., (1980) investigated the yield of alginic acid and mannitol content of *Stoechospermum marginatum* for one year during 1976 and found that the yield of alginic acid varied from 14.5 to 23.8% and the mannitol content varied from 1.2 to 2.7% and were lower than *Sargassum* and *Turbinaria* spp.

Seasonal variation in biochemical constituents of *S. wightii* with reference to yield in alginic acid content has been reported by Reeta (1993) The lipid content showed a reciprocal relation, while carbohydrate a positive correlation with alginic acid content. Seasonal variations in growth, alginic acid and mannitol contents of *Sargassum wightii* and *Turbinaria conoides* growing in the Gulf of Mannar near Mandapam were investigated for a period of two and a half years from August 1965 (Umamaheswara Rao, 1969) and he observed that yield of alginic acid was high during the peak growth and fruiting periods, Mannitol content was at its maximum in the early stages of the growth cycle from May to August and minimum after the initiation of the reproductive receptacles. Reeta (1993) studied the yield and quality of sodium alginate on the pretreatment of *Sargassum wightii* with chemicals such as HCl, NaOH and formalin. Istini *et al*.(1994) compared the yield and physical properties of algin obtained from *Laminaria japonica*, *Eklonia cava* and *Sargassum duplicatum*.collected from Japan. Balakrishnan *et al* (2009b) reported that among the alginophytes in the Gulf of Mannar area, *Stoechospermum marginatum* recorded the richest source of alginic acid closely followed by the species of *Sargassum* and *Turbinaria*.

2.8.3 Carrageenan

Istini *et al*.(1994) compared the yield and physical properties of carrageenan obtained from *Kappaphycus alvarezii* and *Eucheuma spinosum* Collected from the Philippines after alkali treatment at different temperatures. With a view to find out a suitable method for carrageenan extraction from *Kappaphycus alvarezii*, a detailed investigation was made on quantitative and qualitative estimation of carrageenan subjected to different physical and chemical treatments (Mishra *et al*., 2006). Seasonal variation in growth and carrageenan content in *Hypnea valentiae*, *Acanthophora spicifera*, *Laurencia papillosa* were observed for one year from April 1995 to March 1996 (Kaliaperumal *et al*., 2002) and the carrageenan content recorded 11.3%, 6.0% and 8.1% in *H. valentiae, A. spicifera and L. papillosa* respectively. Balakrishnan *et al*. (2009a) found that among the eight species of carragenophytes reported from Gulf of Mannar, *Sarconema filiforme*, *Laurencia papillosa* and the two species of *Hypnea* yielded carrageenan above 60% from most of the study sites and the carrageenan content recorded in *Hypnea* and *Laurencia* exceeded the values reported earlier from other coasts of India.

From the above review of literature, it is evident that a lot of studies have been attempted on culture, harvest, utilization and post harvest technology of seaweeds along Tamil Nadu, Andhra Pradesh and Gujarat and a lot more has to be attempted from Kerala except for resource assessments from certain pockets along the coast. The present investigation may fill the information gaps on identifying promising resources for phycocolloid industry in Kerala in the years to come.