PREVIOUS WORK
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*Kappaphycus* cultivation started during the later half of the 1960s in the Philippines using local varieties selected from the wild (Doty, 1973 and Parker, 1974). The farming has further expanded to other parts of the world like Indonesia, Fiji, Vietnam, China and South Africa (Ask et al., 2001). Later commercial cultivation of *Eucheuma cottoni* (*Kappaphycus alvarezii*) was developed in 1977 jointly by Marine Colloids Corporation (taken over by FMC Corporation and now part of FMC Biopolymer) and Maxwell Doty, University of Hawaii, U.S.A. (Parker, 1974). Test plantings of these seaweeds have been successful in Hawaii (Doty, 1977; Glenn & Doty, 1981 and Russell, 1983), Indonesia (Braud & Perez, 1979 and Adnan & Porse, 1987), China (Liu & Ping, 1984), Fiji (Luxton et al., 1987), and Florida (Dawes et al., 1976) Madagascar (Mollion & Braud, 1993), Vietnam (Ohno et al., 1996) and China (Wu et al., 1989 and Qian et al., 1996) and even in subtropical waters of Japan during warm seasons (Mairh et al., 1986).

The seaweeds most commonly cultivated for the carrageenan industry belong to the genera *Kappaphycus* Doty and *Eucheuma* J. Agardh. The genus has undergone many revisions. During the late 1960s, various *iota* and *kappa* carrageenan producing eucheumatoid species were placed in the genus *Eucheuma*, e.g. *E. spinosum*, *E. cottonii*, *E. striatum*. Later, the tribe Eucheumatodeae and the genus *Kappaphycus* were created (Doty, 1985a, b; 1988) and renamed *E. spinosum* as the synonym of *E. denticulatum* and *E. cottonii* as the synonym of *K. alvarezii*. Doty & Norris, (1985) initiated the revision of genus *Eucheuma* on the basis of their vegetative anatomy, secondary medullary cells and chemical nature of phycocolloid. Much of the taxonomic confusion was addressed by the pioneering work of Maxwell Doty (Doty, 1985a, 1988 and Doty & Norris 1985). Later Doty, (1988) and Trono, (1992; 1997) separated certain species of *Eucheuma* as *Kappaphycus* and Betaphycus mostly based on chemical constituents of *iota*-carrageenan, *beta*-carrageenan, *kappa*-carrageenan etc. The extensive range of morphotypes and the lack of distinct morphological characteristics led to the application of molecular systematics in elucidating this taxonomic confusion. This generic circumscription has been supported for most part
by recent molecular studies (Fredericq et al., 1999; Aguilan et al., 2003; Zuccarello et al., 2006; Dang et al., 2008; Conklin et al., 2009; Zhao & He, 2011 and Tan et al., 2012).


Nevertheless, question remains in the taxonomic identity of commercially produced strains. *K. alvarezi* (Doty) Doty *ex* P. C. Silva is the most widely grown commercial *kappa*-Carrageenan producer which is cultivated in Asia African, and Pacific Island nations (Ask et al., 2001 and Bindu & Levine, 2011). There was an increasing concern about low resistance to stress, decrease in growth rates, as well as reduction in yield and quality of phycocolloids (Dawes & Koch, 1991; Hurtado & Biter, 2007 and Wang et al., 2010). Simultaneously, the worldwide increased in carrageenan consumption has motivated several workers to study the strains with higher quality and variability (Ask & Azanza, 2002). Several authors have reported the production of new strains using various techniques. Rui et al., (1990) studied the effect of ammonium on the growth of *K. alvarezi*. Dawes et al., (1993) studied tissue culture and clonal propagation in *K. alvarezi* and *E. denticulatum* using different media. Doty et al., (1987) and Hurtado, (1995) reported the existence of three colour strains of *K.*
alvarezi with varied pigmentation in the field and culture systems. Aguirre-von-Wobeser et al., (2001) reported differences in physiological characteristics including growth performance and photosynthesis from laboratory studies of morphotypes. Reddy et al., (2003) gave report on tissue culture of K. alvarezi with in vitro somatic embryogenesis and mass clonal production of propagules through somatic embryos. Sahoo & Ohno, (2003) found that K. alvarezi can be cultured in deep seawater with lower dose of nitrogen and produce high growth rate. Additionally, efforts were made to enhance cultivar utilizing molecular techniques, to increase productivity, resistance to disease, herbivory and epiphytism (Cheney et al., 1997, 1998; de Paula et al., 2001; Lombardi et al., 2001, 2006; Yarish et al., 2001; Wu et al., 2003; Msuya & Salum, 2006; Zuccarello et al., 2006; Hayashi et al., 2007a, b; Hayashi et al., 2008a, b; Hurtado & Biter, 2007; Rodriguez & Montaño, 2007 and Yano et al., 2007). Wang et al., (2010) tested methods with microparticle bombardment for gene insertion to produce transgenic strains, improving germplasm resources of K. alvarezi. Liu et al., (2011) identified hypo-osmotically induced genes in Kappaphycus through expressed sequence tag analysis. Recently Zitta et al., (2012) demonstrated that confocal microscopy technique can be used as a rapid and effective tool to distinguish between gametophytic and tetrasporophytic plants of K. alvarezi, in addition to identifying new strains developed through alterations of ploidy level. Pang et al., (2011; 2012) highlighted changes of photosynthetic behaviours in K. alvarezi infected by epiphyte.

To date, only one species of Kappaphycus has been reported from Indian coast. In India, Mairh et al., (1995) conducted culture experiments by introducing K. striatum in Gujarat and K. alvarezi at Mandapam, Tamil Nadu by CSMCRI. Rao & Rao, (1999) reported K. cottonii from Red Skin Island, (Andaman and Nicobar). Sahoo & Sahoo, (2003) initiated the culture of K. alvarezi in India at different environmental conditions using different techniques and was found that the plant grows luxuriantly even at 35°C. Culture at a commercial scale only began when PepsiCo India Holdings Ltd. (PepsiCo) made its entry into the venture with a pilot-scale investment in early 2000.

Kappaphycus farming is a labour intensive activity and the production is often dependent on culture conditions and disease outbreak. Some of the common problems
often encountered in commercial farming are grazing, ice-ice disease and infection by epiphytes. Grazing by fishes, crustaceans such as amphipods and isopods reduced the algal biomass substantially affecting the production.

Trono, (1974) was the first to report emergence of ice-ice disease in Philippines. Uyenco et al., (1981) and Largo et al., (1995a, b) studied the involvement of pathogenic microbes and culture conditions leading to ice-ice disease. Their findings led to the understanding of how stress induced by culture conditions could trigger the pathogenesis. The causative microbes were identified as Vibrio-Aeromonas complex and Cytophaga-Flavobacterium complex. On the other hand, epiphytic infection in farmed Kappaphycus was also reported as early as 1975 by Doty & Alvarez, (1975). However not much interest has been focused on this problem until recently when there has been an increase in epiphyte outbreaks and their impact on production (Critchley et al., 2004; Hurtado et al., 2006 and Vairappan, 2006). Recent investigation of this problem indicated Neosiphonia savateri (Hariot) M.S. Kim et I.K. Lee as the causative organisms and revealed some insights of its symptoms and seasonality at culture farms in Sabah, Malaysia (Vairappan, 2006). Hurtado et al., (2006) described Polysiphonia sp. as another causative organism in the Philippines farms with different type of symptoms. Occurrence of epiphyte outbreaks in Malaysia and the Philippines has resulted in a tremendous reduction of biomass production and decline in carrageenan quality (Vairappan et al., 2007).

Climate change is likely to have widespread and severe ecological and socio-economic implications (Harley et al., 2006; Poloczanska et al., 2007; Rosenzweig et al., 2007; Hoegh-Guldberg & Bruno 2010). With the increasing need for a mechanistic understanding to underpin predictions of how the physical forcing of climate change might translate into impacts in the biological world, the new millennium saw a rapid, almost exponential, increase in the number of studies on the effects of climate change on organisms in both terrestrial and aquatic ecosystems (Harley et al., 2006; Hoegh-Guldberg & Bruno, 2010 and Brown et al., 2011). The potential ecosystem-scale effects of change in CO$_2$ and pH levels was recently demonstrated in Italy at shallow coastal sites near volcanic CO$_2$ vents where the pH levels lower by 0.5 units than the mean ocean pH (ocean acidification levels predicted by 2100 by the IPCC) exhibited
remarkable community-level effects (Hall-Spencer et al., 2008; Riebesell, 2008 and Wootton et al., 2008). Recently, there has been a good deal of interest in the potential of marine vegetation as a sink for anthropogenic Carbon emissions (Nellemann et al., 2009). CO₂ acquisition by marine macroalgae can represent a considerable sink for anthropogenic CO₂ emissions and that harvesting and appropriate use of macroalgal primary production could play a significant role in Carbon sequestration and amelioration of greenhouse gas emissions (Chung et al., 2011).

Although several studies have been undertaken on different aspects of Kappaphycus alvarezii, the seaweeds industries are still struggling with several problems at different cultivation sites. Even though the commercial cultivation of this species is expanding to different parts of Indian Coast; no reports are available on the impact of epiphytism, herbivory and ice-ice studies. Therefore the present investigation has highlighted some of the major problems faced by the Kappaphycus farmers.