PREVIOUS WORK

Marchetti, (1977) first suggested the physical capture of CO₂ from the power plants and then disposing this in the deep ocean. Subsequently several investigators suggested various options for CO₂ capture from the power plants and its subsequent disposal or use (Herzog et al., 1993). Earlier it was assumed that microalgae were susceptible to high CO₂ concentrations. However, some microalgae were reported to grow rapidly even at very high CO₂ concentrations (Miyachi et al., 2003 and De Morais and Costa, 2007a). Seckbach et al., (1970) reported that the red microalgae *Cyanidium caldarium* could grow even in 100% CO₂ although the growth rates can be much lower than that of green or blue-green algae. Similar growth of algae in 100% CO₂ has been reported in *Cyanidioschyzon merollae* and *Galdieria partitec* (Kurano et al., 1995). Hanagata et al., (1992) and Takano et al., (1992) reported that *Scenedesmus* sp. and a marine cyanobacterium *Synechococcus* sp. have the ability to tolerate high carbon dioxide and temperature; which makes them suitable for the biofixation of carbon dioxide from thermoelectric power plants.

Kodama et al., (1993) found that *Chlorococcum littorale* isolated from a saline pond in Japan can grow rapidly at a CO₂ concentration as high as 40% and even at 60% CO₂ if the concentration was elevated stepwise in 10% increment. Watanabe and Hall, (1995) investigated the photosynthetic CO₂ fixation in the filamentous cyanobacterium *Spirulina platensis* with 4% CO₂. Yanagi et al., (1995) observed the growth response of *Chlorella* sp. HA-l against an air containing 10 % CO₂ and NOₓ while Yeoung-Sang et al., (1997) observed that after adaptation to 5% CO₂ the growth of *Chlorella vulgaris* was significantly improved at a typical concentration of CO₂ in flue gas of 15%. Yang and Gao (2003) also studied the impact of high CO₂ on growth and photosynthesis, in *Chlamydomonas reinhardtii, Chlorella pyrenoidosa*, and *Scenedesmus obliquus*. De Morais and Costa, (2007a) observed the maximum specific growth rates and biomass productivity of *Chlorella kessleri* when cultivated with 6% and 12% CO₂ and with a maximum biomass productivity was achieved at 6% CO₂.
Miyachi et al., (2003) showed that when the cells were grown under high CO$_2$ conditions, although the cells lose their ability to efficiently fix CO$_2$ under a limiting concentration of dissolved inorganic carbon (DIC), instead there was an increase in the rate of maximum photosynthesis under saturating DIC conditions in some species of microalgae such as Chlorella. However, the maximum rate did not change in other species, such as Chlamydomonas. Laboratory-scale experiments were conducted by Kurano and Miyachi, (2005) which focused on the effect of CO$_2$ concentration on C. littorale growth and found that growth rate was highest at CO$_2$ concentrations of 2% in the air and decreased at higher concentrations.

De Morais and Costa, (2007c) observed that Spirulina sp., Scenedesmus obliquus and Chlorella vulgaris could grow in CO$_2$ concentration up to 18%. Douskova et al., (2009) also treated CO$_2$ from flue gas in C. vulgaris to decrease the biomass production costs. Widjaja, (2009) studied the effect of CO$_2$ concentration and nitrogen concentration on lipid content as well as the effect of drying temperature during lipid extraction in C. vulgaris. Borkenstein et al., (2011) cultivated Chlorella emersonii in 5.5L airlift photobioreactors and provided flue gas as a CO$_2$ supplier.

Only a few reports are available on the ultrastructural changes in microalgae after carbon dioxide treatment. The changes in chloroplast structure after CO$_2$ treatment were reported only in Chlorella pyrenoidosa by Gergis, (1972). Difference in cell wall appearance between high and low CO$_2$ grown cells of Anabaena variabilis was reported by Marcus et al., (1982). Sasaki et al., (1999) reported the development of vacuoles in Chlorococcum littorale after 40% CO$_2$ treatment and the accumulation lipid droplets in Isochrysis sp. after 10% CO$_2$ treatment was reported by Liu and Lin, (2001). Izumo et al., (2007) studied the pyrenoid and stroma starch changes after 3% CO$_2$ treatment in Chlorella.

Similarly growth of some seaweeds species, such as Porphyra yezoensis, Gracilaria sp., Gracilaria chilensis, were enhanced when grown at CO$_2$ levels 2-3 times the present atmospheric CO$_2$ concentration (Gao et al., 1991 and Gao et al., 1993). These species were capable of using HCO$_3^-$, yet they showed carbon limited photosynthesis in natural seawater. Growth of the red alga Lomentaria articulata, a
non bicarbonate user, was stimulated by enriched CO₂ in aeration (Kübler et al., 1999). On the other hand, a decrease of growth rate caused by elevated CO₂ has also been reported, in *Gracilaria tenuistipitata*, *Porphyra leucostica* and *Porphyra linearis* (Israel et al., 1999; García-Sânchez et al., 1994 and Mercado et al., 1999). Zou and Gao, (2009) also studied the effects of elevated CO₂ on the red seaweed *Gracilaria lemaneiformis* (Gigartinales, Rhodophyta) grown at different irradiance levels.

Published literature did not reveal any information about the impact of high CO₂ on *Chlorella protothecoides*, *Scenedesmus obliquus* and *Chlorococcum granulosum* and one red seaweeds *Kappaphycus alvarezii*. Hence, in the present investigation, an attempt is made to study the effects of different CO₂ concentration under different temperature, photoperiod conditions on the above algal species.