method

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*Kappaphycus alvarezii* an economically important red tropical seaweed, is used as significant source for carrageenan that is used in various food, pharmaceutical, industrial and biotechnological applications. The commercial cultivation of *K. alvarezii* was initiated in the Philippines in the year 1960 and later it was introduced in many countries including India for experimental or commercial cultivation. The rapid growth rates, easy dispersal and ways to cultivate *K. alvarezii* makes the species adaptable and flourish in new habitats. It is reported that the species can double its biomass in 15-30 days (Trono, 1992 *Bull. Mar. Sci. Fish. Kochi Univ.*, 12: 51-65) when cultivated in appropriate sites and can spread by means of vegetative fragmentation as well as by sexual reproduction. In India, the successful cultivation and harvesting of *K. alvarezii* was witnessed along Mandapam coast during the last two decades, which could be attributed to the favourable hydrobiological and environmental conditions, prevailing locally. High sea surface temperature (SST), high intensity of light, hypertrophic nutrient conditions and elevated degree of water motions are few environmental conditions which are congenial for the growth and cultivation *K. alvarezii* (Doty, 1990, *Aquaculture*, 84, 245–255).

Similar ideal conditions for the growth and cultivation of *K. alvarezii* prevail along the Saurashtra coast. However till date, only a few attempts have been made to cultivate the species here. The high tidal amplitude occurring on this coast limits the spread of the raft method of

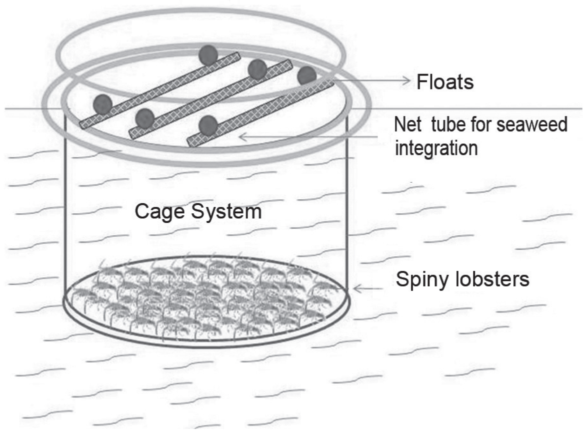


Fig. 1. Diagrammatic representation of net-tube method of seawead cultivation in open sea cages stocked with lobsters

seaweed cultivation. This method is also considered to be laborious that requires time for seeding, maintenance as well as harvesting, leading to higher labour costs. In order to arrive at more efficient techniques, an attempt to try the net-tube method for cultivation of *K. alvarezii* in open sea cages of Gujarat as an avenue for income generation was done (Fig. 1).

The study was carried out in the open sea cages (Station 1: 20º 88' 96.20" N, 70º 38' 77.49" E and Station 2: 20º 88' 94.25" N, 70º 38' 82.87" E), installed by ICAR- CMFRI off Veraval, Gujarat. The seeds of *K. alvarezii* were collected from Gujarat Livelihood promotion Corporation (GLPC) farm at Simar, Gujarat. After acclimitisation of the live material in the wet lab they were transferred to open sea cages, packed in wet jute bags to avoid desiccation. The live materials were tied to the net and kept in floating condition in cages. The Daily Growth Rate (DGR), Specific Growth Rate (SGR) and Biomass Yield (BA) for *K. alvarezii* was studied and the results indicated post monsoon season as the most favourable season with good growth. Keeping this in mind, the experiments were conducted from January to February 2016 by placing six net tubes in two cages (three in each cage) with a known quantity of *K. alvarezii,* in each net-tube (Fig. 1).

Net-tube 4 m length used for cultivation of *K. alvarezii*

Seeding and tying of seeded net- tubes at sea cage sites

Harvests were made at an interval of 50 days. The open sea cages were also stocked with the lobster *Panulirus polyphagus* at different stocking densities.

Net-Tube fabrication was done using fishing nets of square mesh (10 mm) used as a bag net of 3-4 m length and 40 cm diameter. The nets were stitched so as to divide the net into six compartments of 30×70 cm each. An average 1000 gm of good quality seed material was placed in each net-tube. In order to prevent the escape of seed materials, both ends of the tube were tied with 20 mm nylon rope. This seeded net-tube was tied to the inner frame of the circular GI cage stocked with the lobsters. The growth of *K. alvarezii* was evaluated by measuring daily growth rate (DGR), Specific Growth Rate (SGR) and biomass yield (BA) as indicated below.

DGR (% day$^{-1}$) = ln (Wf / $W_0$) / t × 100,

where Wf is the final fresh weight after the t days of culture, and $W_0$ is the initial fresh weight (g).

Specific Growth Rate = (Nt/$N_0$))/t x 100

where, $N_0$ is initial wet weight and Nt is wet weight at day t.

Biomass (BA) of seaweed was determined by weighing the fresh harvested plant material. The quantity of fresh biomass obtained per net-tube was determined and presented as a crop yield (kg FW tube$^{-1}$).

The water temperature and atmospheric temperature were recorded. Salinity, pH and dissolved oxygen of the water samples were analyzed using a multiparameter kit. Nitrate and phosphate levels were estimated using standard procedures. The atmospheric temperature and sea surface temperature varied between 25.37 - 30.69°C and 26.37 - 30.46°C respectively. The salinity varied between 33 to 35 ppt. The dissolved oxygen content was 4.83 -6.14 mg/l and pH ranged from 8.14 to 8.25. Nitrate and phosphate levels ranged between 0.67 to 1.31 μ mol $L^{-1}$ and 0.17 to 0.42 μ mol $L^{-1}$ respectively. The water parameters were optimum during the culture period and hence supported the growth of seaweed in cages.

Growth studies during the cultivation period of January to February 2016, until crop was harvested after 50 days of culture was completed. The seaweed was harvested at 7 day intervals in order to determine the DGR, SGR and BA of seaweeds from each tube from both the cages. DGR varied from 5.79 - 7.76 % $day^{-1}$ between the tubes with highest biomass (1500 – 1772 g FW $line^{-1}$) observed during the first seven days of culture period. Net-tube samples harvested after 14 days showed the highest growth rate and commendable DGRs (6.65 – 7.99% $day^{-1}$), with corresponding specific growth rate (6.87 – 8.31% $day^{-1}$) and biomass yield (2485 – 2897 g FW $line^{-1}$). The minimum DGRs, SGR and BA were observed during $35^{th}$ and $42^{nd}$ days of sampling.

A consistent growth was observed during the study period, with the most favourable condition during the month of February, as the DGR and biomass showed the highest value during that time. A DGR above 3.5% $day^{-1}$ is considered a good value for commercial cultivation (*FAO Fisheries Technical Paper,* 1987, 281 : 123-161). The present study showed DGR value above 3.5% $day^{-1}$, thus signifying high potential of *K. alvarezii* cultivation along the Saurashtra coast of Gujarat. High tidal amplitude and rough sea conditions do not support raft cultivation method of seaweed farming. Hence the net-tube farming method can be a promising alternate method for seaweed cultivation where above mentioned sea conditions prevail 2011. The present study clearly indicates the suitability of net-tube method for year around seaweed cultivation because of cost effectiveness, minimal loss of seedlings and maximum harvesting of *K. alvarezii*. The horizontally placed net-tube give support to the plants when fully grown and it also helps in minimizing the breakage and dislodging of fronds by wave action and water currents.

In conclusion more attention needs to be give to net-tube method of seaweed cultivation in Saurashtra coast and it should be popularized as an effective means for income generation as cultivation is easy and doesn't employ laborious techniques. Net-tube cultivation method serves as a promising alternative for seaweed farming method over raft culture, along the Gujarat coast. Cultivation of *K. alvarezii* in net-tube can also be used as part of Integrated Multi-trophic Aquaculture (IMTA) which is designed to mitigate the environmental problems caused by aquaculture.