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Note

First successful trial of seaweed (*Kappaphycus alvarezii*) cultivation in Karnataka, India

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Abstract

This study highlights the successful raft-based cultivation of *Kappaphycus alvarezii* in the Yadamavinahole Estuary, Uppunda, Karnataka over a period of 72 days during pre-monsoon season (February to April, 2025). A total of 20 net tubes were deployed, yielding 180 kg of fresh biomass and the mean biomass per tube was 8.94±0.10 kg. The growth performance was promising with a specific growth rate of 2.06±0.04% day^{-1} and a daily growth rate of 2.16±0.03% day^{-1}. Optimal water quality conditions supported consistent growth. The trial success underscores the potential for scalable seaweed farming in the region and provides essential insights for enhancing future commercial cultivation practices.

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Seaweed culture has rapidly gained prominence in India's coastal economy, driven by strong government support and its multifaceted benefits. Seaweed farming not only provides an alternative and sustainable income source for thousands of coastal families, especially women, but also offers substantial environmental advantages by absorbing CO_2 and improving ocean health. With India's diverse coastline and over 800 identified seaweed species, the sector holds immense untapped potential for expansion into high-value products for food, pharmaceuticals, and agriculture, as well as for export growth. Despite currently contributing less than 1% to global seaweed production, recent policy initiatives, infrastructure investments, and research collaborations are positioning seaweed culture as a transformative force in India's blue economy and rural development. Out of around 844 seaweed species, about 60 are commercially valuable (Kumar *et al.,* 2025).

According to FAO (2024), global seaweed production has reached an impressive 36.5 million t (wet weight), valued at USD 17 billion, highlighting the immense economic potential of seaweed farming worldwide. In India, approximately 47,000 t (wet weight) of seaweed, primarily *Sargassum*, *Turbinaria*, *Gracilaria*, and *Gelidiella* species are harvested annually from natural beds (CMFRI, 2023). Despite having an estimated production potential of 0.26 million t per year (wet weight), India contributes less than one percent of global output, with the domestic seaweed market valued at approximately ₹200 crore annually (Kaladharan *et al*., 2019: Johnson *et al*. 2023a). Seaweed mariculture in India dates back to 1964, when the ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI), under the Ministry of Agriculture and Farmers' Welfare, initiated research and development activities in this sector. During the 1980's, ICAR-CMFRI also developed and demonstrated cottage industry techniques for agar extraction from *Gracilaria* spp. and alginic acid from *Sargassum* spp. These efforts catalysed the establishment of numerous small-scale agar processing industries, particularly in Madurai, Tamil Nadu. Despite these early advancements, seaweed farming in India remained largely experimental until the early 2000's.

A significant milestone was achieved in the year 2000 with the commencement of large-scale farming of the carrageenan-yielding red seaweed, *Kappaphycus alvarezii*. This initiative was supported by PepsiCo India, and technically guided by CSIR-Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI). By 2012, contract farming of *K. alvarezii* peaked at 1,500 t of dry weight (≈ 8-12% of wet weight), and between 2005 and 2015, over 70,000 t (wet weight) were harvested, generating an estimated annual turnover of ₹2 billion (Kaladharan *et al*., 2019).

Employment in fisheries and aquaculture increased from 41.3 million in 1995 to a peak of 63.1 million in 2018, with regional variations and a slight decline thereafter (FAO, 2024). In India, seaweed farming has emerged as a promising supplementary livelihood, particularly empowering women, who constitute nearly 60% of the workforce in this sector. Short cultivation cycle makes it especially suitable for women's participation, as noted by the Council for Environment, Energy and Water (CEEW). Beyond livelihoods, seaweed farming aligns with India's objectives in the bio-economy, coastal development, and green economy (Panicker, 2025).

In India, seaweeds such as *K. alvarezii*, *Gracilaria edulis*, *Gracilaria verrucosa*, and *Gelidiella acerosa* are being cultivated under Integrated Multi-Trophic Aquaculture (IMTA) systems. Several studies have confirmed the successful integration of seaweeds into IMTA (Dash *et al*., 2009; Ganesan *et al*., 2013; Sukhdhane *et al*., 2017; Biswas *et al*., 2019; Sarkar *et al*., 2022). The present study involves a farming trial of *K. alvarezii* in combination with *Trachinotus blochii* (silver pompano) cultured in cages and *Perna viridis* (green mussel) grown on rafts within an IMTA framework.

Karnataka, with a coastline spanning 343.3 km, boasts 26 estuaries covering a combined area of 7,213.5 ha across three coastal districts. Specifically, Dakshin Kannada has 5 estuaries, Udupi has 8 estuaries and Uttara Kannada features 13 estuaries covering 1,140 ha, 1,885 ha and 4,188 ha respectively (De, 2011). Uttara Kannada and Udupi districts in Karnataka have been recognized as potential zones for seaweed farming, offering a total cultivable area of 1,579 ha (Johnson *et al*., 2023a).

Uppunda, located in Byndoor Taluk of Udupi District, Karnataka, has emerged as a key hub for the adoption and demonstration of innovative aquaculture practices, particularly cage farming of fish, bivalve rearing and IMTA. This coastal village is gaining recognition for its progressive approach to sustainable aquaculture development. The Yadamavinahole Estuary at Uppunda (13°47'44.6" N; 74°37'33.3" E) was selected as the experimental site for the present seaweed farming trial (Fig. 1). The estuary's favourable hydrodynamic conditions, salinity profile, and nutrient availability during the late post-monsoon and pre-monsoon season, make it an ideal environment for seaweed cultivation, particularly under IMTA systems integrating finfish and bivalve species.

Seaweed production in India has traditionally been concentrated in the southern coastal states, particularly Tamil Nadu. Recognising the untapped potential along the Karnataka coast, ICAR-CMFRI initiated a pilot seaweed farming trial in the region during 2015-16. These initial trials were conducted at multiple sites in Udupi District, including Uppunda, Mulki Rocks, Kundapura, Koderi, and Paduthonse. While ICAR-CMFRI spearheaded these efforts, several NGOs and other institutions also explored seaweed cultivation in the region. However, most of these parallel initiatives were unsuccessful due to technical and operational challenges, including high water currents, turbid conditions prevalent in many estuarine waters, and limited availability of quality seed material.

Fig. 1. Arial view showing the study site and the IMTA unit

The Mangalore Regional Centre of ICAR-CMFRI, achieved a significant milestone in 2025 by successfully establishing the first commercially viable seaweed farming initiative in Karnataka. This pioneering effort was made possible with financial support from the National Fisheries Development Board (NFDB), which played a crucial role in facilitating infrastructure development, procurement of farming materials, and capacity building of coastal communities. This landmark success marks a turning point for the state's coastal aquaculture sector. For the first time in Karnataka, seaweed cultivation was successfully implemented and demonstrated alongside the farming of high-value fish species and green mussels, showcasing the potential for diversified and sustainable coastal livelihoods.

Seaweed seedlings of *K. alvarezii* were procured from the Mandapam Regional Centre of ICAR-CMFRI and subjected to a period of acclimatization to local environmental conditions prior to deployment. Immediately after collection, the seed material was packed in gunny bags and kept soaked in seawater during transport to the culture site. Subsequently, the seaweed was acclimatised to the site-specific salinity of 31.7 ppt by periodically spraying estuarine water onto the gunny bags. For the cultivation trial, a floating raft structure measuring 20 × 10 feet was fabricated using durable PVC pipes to ensure buoyancy and structural integrity in the estuarine environment. The cultivation employed the tube method, wherein high-density polyethylene (HDPE) food-grade net tubes with a mesh size of 18 mm were used to contain the seaweed seedlings. Each net tube was loaded with approximately 2 kg of freshly acclimatised seaweed biomass. In total, 20 tubes of *K. alvarezii* were uniformly tied to the raft, ensuring adequate spacing for optimal growth and water exchange.

The raft was strategically deployed in the estuarine site alongside a bivalve rack and finfish cages. To maintain positional stability and withstand wave action, concrete block anchors were securely placed on both ends of the raft, enabling efficient cultivation while minimising the impact of water currents and tidal fluctuations on seaweed growth. The seaweed cultivation trial was carried out over a period of 72 days during pre-monsoon season (from the last week of February to first week of May). During this time, the floating raft system was regularly monitored to ensure optimal growth conditions and structural integrity. Routine maintenance included the periodic cleaning of the net tubes to remove any debris, silt, or fouling organisms that accumulated due to tidal currents, to ensure adequate water flow, and minimise the risk of disease or stunted growth. Monitoring also included visual inspection of seedling health, tube integrity, and the overall stability of the raft system throughout the culture period.

Water quality parameters such as temperature, salinity, dissolved oxygen (DO), pH and total dissolved solids (TDS) were recorded using Multi-parameter Water Quality Checker (Horiba U-50, HORIBA Advanced Techno Co., Ltd., Japan). Growth performance was monitored from February to May 2025, until the crop was harvested. *K. alvarezii* growth was assessed based on its daily growth rate (DGR), biomass yield (BA) and specific growth rate (SGR).

The daily growth rate (DGR) was calculated using the formula suggested by Yong *et al.* (2013):

Daily growth rate = $[(W_t/W_0)^{1/t} - 1] \times 100$ %

where, W_0 = Initial wet weight
W_t = Final wet weight and t = Days of culture.

Biomass (BA) of the seaweed was calculated by measuring the weight of the freshly harvested seaweed material. The amount of fresh biomass collected from each net tube was recorded and expressed as crop yield in kg of fresh weight per tube (kg FW $tube^{-1}$).

The specific growth rate (SGR) was calculated using the formula suggested by Luhan and Sollesta (2010):

Specific growth rate (%) = $(\ln W_t - \ln W_0 / t) \times 100$

where, $\ln W_0$ = Natural logarithm of initial wet weight
and $\ln W_t$ = Natural logarithm of final wet weight at day t.

Monitoring of water quality parameters is essential for understanding the influence of local hydrographic conditions on seaweed growth and for ensuring the overall health of the aquaculture system. The observed water quality parameters were in the optimal range for the growth of seaweed as per Sujatmiko *et al*. (2024) (Table 1).

At the end of the culture period, the total fresh yield harvested from net tubes amounted to 180 kg. The biomass of the harvested seaweed, [measured in fresh weight (FW)] per tube, was 8.94±0.10 kg (Fig 2), showcasing the ability of the species to produce substantial biomass under the given environmental conditions (Sujatmiko *et al*., 2024). The specific growth rate recorded was 2.06±0.04% day^{-1}. Furthermore; the daily growth rate (DGR) recorded during the culture period was 2.16 ± 0.03% day^{-1} (Fig 3) which indicates healthy and efficient growth of the seaweed under the farming conditions.

Johnson *et al*. (2023b) reported that a seaweed raft integrated with cobia and stocked with 60 kg of seaweed at Mandapam produced about 320 kg per raft within a 45-day culture period. In the present study, an yield of 180 kg per raft was obtained from an initial stocking of 40 kg over 72 days; when extrapolated to a 60 kg stocking level, the estimated yield would be about 270 kg per raft, representing nearly 75% of the production reported from Mandapam. This suggests that the current study location holds

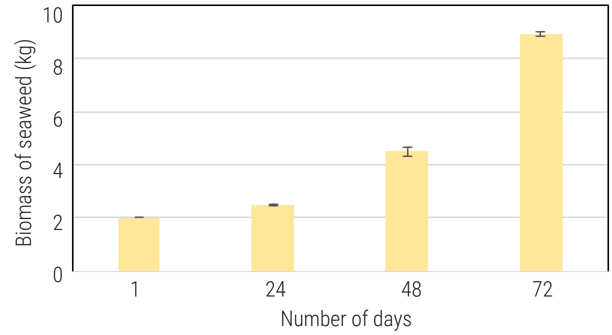

Fig. 2. Increase in biomass of seaweed over the culture period

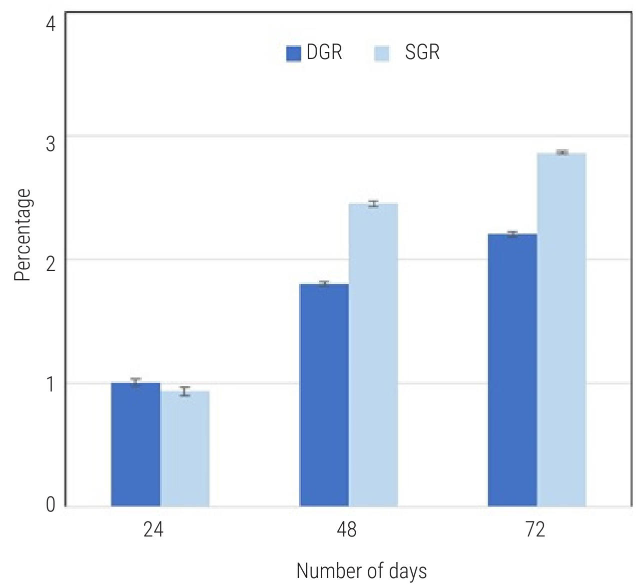

Fig. 3. Specific growth rate and daily growth rate of seaweed over the culture period

Table 1. Water quality parameters from the seaweed cultivation site. Values are expressed as Mean±SE

Parameters	Range	Mean ± SE
Temperature (°C)	31.5 - 33.19	32.49 ± 0.47
pH	7.97 – 8.03	8.02 ± 0.02
Salinity (ppt)	31.77 – 33.70	32.74 ± 0.56
Dissolved oxygen (mg l^{-1})	2.76 – 4.46	3.52 ± 0,50
Total dissolved solids (mg l^{-1})	29.70 – 30.60	30.10 ± 0.26
Phosphate (mg l^{-1})	0.009 - 0.074	0.031 ± 0.02
Nitrate (mg l^{-1})	0.124 - 0.223	0.160 ± 0.02

promise for small-scale seaweed cultivation, although the productivity is slightly lower than that reported in Mandapam, possibly due to differences in environmental conditions.

Earlier, Sukhadhane *et al*. (2017) reported that *K. alvarezii* cultivated in open sea cages with lobsters exhibited a daily growth rate (DGR) exceeding 3.5%, a benchmark considered suitable for commercial-scale farming. In the present study, however, the DGR was recorded at 2.16±0.03% day^{-1}, indicating the need for improved cultivation methods if commercial production is to be pursued. The SGR recorded in the present study is consistent with the trend reported by Luhana and Sollesta (2010), though relatively lower due to the estuarine culture conditions, where high turbidity limits light penetration compared to open sea waters. This pilot seaweed trial made use of just 0.0018 ha, a small fraction of Karnataka's total potential seaweed farming area of 1579 ha (Johnson *et al*., 2023a). Based on the observed yield of 180 kg per raft of *K. alvarezii* from 0.0018 ha, the projected productivity amounts to roughly 100 t ha^{-1}

Expansion of seaweed cultivation in the 1,579 ha could potentially achieve a wet seaweed production of approximately 78,950 t per harvest cycle. These findings underscore the significant scalability and commercial potential of seaweed farming in the state, particularly if supported by suitable infrastructure, policy frameworks and community engagement. Incorporating seaweed as a component of IMTA alongside bivalve and fish farming can create synergistic interactions that enhance overall productivity while helping maintain good water quality in the ecosystem.

The successful pilot seaweed farming initiative by ICAR-CMFRI in Karnataka represents a major milestone in the state's entry into India's rapidly growing blue economy. Although much of Karnataka's 343.3 km coastline lacks extensive protected bays and is influenced by significant riverine influx, which constrains large scale seaweed farming, certain sheltered and seasonally suitable areas offer scope for seaweed cultivation as a supplementary livelihood option as well as for localised industrial growth. The adoption of IMTA which combines seaweed farming with the cultivation of high-value fish and shellfish, offers a promising livelihood diversification strategy, particularly for empowering coastal communities and fisherwomen. This integrated approach not only enhances income opportunities but also supports ecological balance. With a strategic combination of community participation, scientific innovation, appropriate infrastructure, efficient market linkages and policy support, seaweed farming in Karnataka, if implemented in carefully identified, sheltered and seasonally suitable areas, has the potential to develop as a viable and sustainable economic activity.

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