International Journal of Scientific Multidisciplinary Research (IJSMR)
Vol. 4, No. 6, 2026: 893 - 912

Performance Analysis of the Seaweed (*Kappaphycus alvarezii*) Cultivation System Based on Culture Units: A Comparison of Longline and Floating Raft Methods

Yuli Andriani[1], Devina Khunti Nalibhrata[2*]
[1]Departement of Fisheries, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran
[2]Master's of Fisheries Science, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Indonesia
Corresponding Author: Devina Khunti Nalibhrata devina22003@mail.unpad.ac.id

ARTICLEINFO

Keywords: systematic review, growth parameters, environmental factors, seedling quality, biomass production

Received : 09, April
Revised : 20, May
Accepted: 30, June

ABSTRACT

Kappaphycus alvarezii is a commercially important red seaweed cultivated in tropical countries. This systematic review compared longline and floating raft cultivation methods based on articles published between 2017 and 2026. Growth parameters ranged from 0.02% to 8.4% per day, with optimal growth at 3–6% per day. Protected floating raft systems (e.g., floating cages, horinets) produced higher biomass and survival due to reduced herbivory and wave damage. Longline systems achieved higher individual growth rates under calm, low-pest conditions. Depth (20–50 cm), current velocity (20–40 cm/s), and tissue-cultured seedlings were key productivity modulators. No single method is universally superior; selection depends on local environmental conditions. Practical recommendations for farmers are provided.

DOI: https://doi.org/10.55927/ijsmr.v4i6.52
https://journalijsmr.my.id/index.php/ijsmr

INTRODUCTION

Seaweed is a marine agricultural commodity of strategic economic value for tropical and subtropical countries, particularly in Southeast Asia. *Kappaphycus alvarezii* has become a major aquaculture commodity due to its high carrageenan content and wide applications in the pharmaceutical, cosmetic, and food industries (Zainuddin and Rusdani, 2018). The carrageenan content of *Kappaphycus alvarezii* ranges from 8–25 percent of dry weight, making it highly valuable in the global market (Widiastuti, 2007). Taxonomically *Kappaphycus alvarezii* is one of the most widely cultivated red seaweed species (Rhodophyta, family Solieriaceae) for carrageenan production in tropical regions, including Indonesia, the Philippines, and several other Southeast Asian countries (Rasniyad *et al.,* 2021; Patadjai *et al.,* 2024; Kasim and Mustafa, 2017).

Economically, this commodity holds a strategic position in the small-scale aquaculture system because it requires no additional feed, is easily adopted by small- and medium-scale fishermen, and has a stable market value in the food, cosmetic, pharmaceutical, and feed industries (Budiyanto *et al.,* 2019; Asni 2015). In Indonesia, *Kappaphycus alvarezii* cultivation has become a key pillar of the coastal economy, particularly in the regions of Sulawesi, Nusa Tenggara, and Bali, while also contributing to increased household income and employment for coastal communities (Hardan *et al.,* 2020; Wulandari, 2023).

Indonesia itself is the world's second-largest seaweed producer after China. National production saw a significant increase from 1.7 million tons in 2007 to 3.9 million tons in 2010, and continued to rise, reaching approximately 11 million tons in 2016 (Nisa *et al.,* 2024). Additionally, seaweed accounted for approximately 21.8 percent of Indonesia's total fishery exports in 2023. More than 20,000 seaweed farmers are spread across strategic regions such as Southeast Sulawesi, South Sulawesi, East Nusa Tenggara, and Bali (Kasim and Asnani, 2017). With the support of more than 17,000 islands and extensive coastal waters, Indonesia has great potential for the sustainable development of seaweed cultivation.

The success of *Kappaphycus alvarezii* cultivation depends heavily on selecting cultivation methods that align with local conditions, geographical characteristics, and the economic capacity of the farmers (Rachmawati and Abdillah, 2019). Cultivation systems commonly used in Indonesia include the longline method, floating rafts, and verticulture (Wijayanto *et al.,* 2011). The longline method is a traditional technique still predominantly used by small and medium-scale farmers, involving a horizontal line system stretched across the water's surface using buoys and anchors, with seedlings tied at intervals of approximately 20–30 centimeters. This method is widely chosen because it is simple, low-cost, and uses readily available materials.

In contrast, floating rafts are a more structured aquaculture system that uses bamboo frames or synthetic materials floating on the water's surface, thereby enabling more controlled management and higher productivity potential (Patadjai *et al.,* 2024). Meanwhile, verticulture utilizes the water column vertically to a depth of 3–5 meters and is reported to significantly increase productivity compared to surface methods. Each method has its own characteristics, advantages, and limitations in terms of production efficiency, product quality, and economic sustainability.

The growth of *Kappaphycus alvarezii* is influenced by the complex interaction of physical, chemical, and biological environmental factors. Water quality parameters such as an optimal temperature of 20–30°C, salinity of 28–34 ppt, pH of 7.0–8.5, and light penetration of 1.5–3.0 meters play a crucial role in supporting photosynthesis and plant metabolism (Kasnir *et al.,* 2023; Jasman *et al.,* 2024). Current velocity is also a key factor as it contributes to enhancing nutrient availability through water mass mixing (Cokrowati *et al.,* 2020). The variability of these environmental conditions is both spatial and temporal, resulting in differences in growth responses across cultivation sites.

Although production potential is very high, seaweed cultivation in Indonesia still faces challenges in the form of unstable productivity and product quality. The choice of cultivation system has been shown to influence specific growth rate, daily growth rate, and absolute growth rate (Rachmawati and Abdillah, 2019). Several studies indicate that in floating raft systems, specific growth rates can reach 3.69 percent per day with herbivore damage levels around 5 percent, whereas in longline systems, rates range from 2.43 to 4.85 percent per day with damage levels up to 30 percent (Kasim and Asnani, 2017). Another study indicates that the horizontal net method yields a growth of 40.5±6.2 grams, significantly higher than the longline method, which yields only 8.2±5.2 grams (Patadjai *et al.,* 2024). This variation demonstrates that there is no single universally optimal method; rather, it depends heavily on environmental conditions and the location of the aquaculture operation.

Despite the growing number of studies on *Kappaphycus alvarezii* cultivation, significant research gaps remain in understanding the comparative performance of longline and floating raft systems. Most previous studies have focused on a single cultivation method or specific variables, such as growth rate, cultivation depth, or seedling quality, resulting in fragmented knowledge that limits comprehensive evaluation of cultivation performance (Kasim & Mustafa, 2017; Kasnir *et al.*, 2023; Cokrowati *et al.*, 2020; Patadjai *et al.*, 2024). Furthermore, biological indicators such as *Daily Growth Rate* (DGR), *Specific Growth Rate* (SGR), absolute growth, and biomass production are often assessed independently from environmental factors, including depth, current velocity, temperature, and salinity. This lack of integrated analysis hinders a thorough understanding of how cultivation methods interact with environmental conditions to influence productivity.

Another important limitation is the inconsistency in reporting growth performance and the limited inclusion of economic assessments, such as production costs, profitability, benefit-cost ratios, and return on investment, which restrict evidence-based decision-making for farmers and policymakers (Nisa *et al.*, 2024). Despite the increasing body of literature, no systematic review has comprehensively compared longline and floating raft cultivation methods by simultaneously integrating biological, environmental, and economic dimensions across multiple locations and study periods. Therefore, this systematic review aims to synthesize evidence published between 2017 and 2026 to compare the performance of both cultivation systems, evaluate the influence of key environmental and seed quality factors, provide evidence-based recommendations for method selection, and identify priorities for future research to support the sustainable development of *Kappaphycus alvarezii* aquaculture (Kasnir *et al.*, 2023; Pong-Masak & Sarira, 2020; Cokrowati *et al.*, 2020; Nisa *et al.*, 2024).

Given these conditions, a comprehensive study based on a systematic review is needed to synthesize various empirical findings regarding the performance of the longline and floating raft methods in *Kappaphycus alvarezii* cultivation. This approach is expected to provide a more complete understanding of the relationship between aquaculture methods, environmental conditions, and production yields, thereby generating more accurate and practical recommendations for the development of efficient and sustainable seaweed aquaculture in Indonesia.

LITERATURE REVIEW

Kappaphycus alvarezii as an Aquaculture Commodity

Kappaphycus alvarezii is a red seaweed (Rhodophyta, family Solieriaceae) widely recognized as one of the most economically important macroalgae in tropical aquaculture due to its high carrageenan content, which ranges from 8 to 25 percent of dry weight (Widiastuti, 2007). Carrageenan is a sulfated polysaccharide extensively used as a gelling, thickening, and stabilizing agent in the food, pharmaceutical, and cosmetic industries (Zainuddin and Rusdani, 2018). The species is capable of rapid vegetative growth, doubling its biomass within 15 to 30 days under optimal conditions, making it highly suitable for commercial-scale cultivation (Rudke *et al.*, 2020). In Indonesia, *Kappaphycus alvarezii* cultivation has become a key pillar of the coastal economy, particularly in Sulawesi, Nusa Tenggara, and Bali, contributing significantly to household income and employment among coastal communities (Hardan *et al.*, 2020).

Longline Cultivation Method

The longline method is the most widely practiced cultivation technique for *K. alvarezii* in Indonesia and across Southeast Asia. It employs a main rope stretched horizontally near the water surface, supported by buoys and anchored at both ends, with seedlings tied at intervals of approximately 20 to 30 cm (Afandi and Syam, 2020). The system is favored for its simplicity, low construction cost, and ease of maintenance, making it accessible to small- and medium-scale farmers. However, the open structure of the longline system exposes seaweed to herbivorous fish grazing and mechanical damage from waves and strong currents, which can reduce productivity significantly (Kasim and Mustafa, 2017). Studies have reported specific growth rates ranging from 2.43 to 8.4 percent per day under this method, depending on location and environmental conditions (Nisa *et al.*, 2024; Kasim and Mustafa, 2017).

Floating Raft Cultivation Method

The floating raft method uses a bamboo or synthetic frame structure anchored at the water surface, providing greater physical stability compared to the longline system (Masak and Sarira, 2016). Variants of this system include floating cages, horinets, tubular nets, and verticulture arrangements, all of which offer additional protection against herbivory and wave disturbance (Patadjai *et al.*, 2024; Pong-Masak and Sarira, 2020). As a result, floating raft systems tend to produce higher total biomass per cultivation cycle, though at a higher construction and maintenance cost. Wijayanto *et al.* (2011) reported a growth rate of up to 6.9 percent per day in floating raft systems, while Kasim and Mustafa (2017) found that floating cages produced 38.8 kg over 40 days compared to only 22.5 kg in open longline systems under the same initial conditions.

Environmental Factors Affecting Seaweed Growth

The productivity of *K. alvarezii* is strongly influenced by environmental parameters including water temperature, salinity, current velocity, light intensity, and cultivation depth. The optimal temperature range is 27 to 30°C, with growth declining significantly above 31°C due to increased respiration and oxidative stress (Kasim and Mustafa, 2017; Rajaram *et al.*, 2020). Salinity between 28 and 34 ppt is considered optimal, while values above 36.8 ppt have been associated with reduced production (Kasnir *et al.*, 2023). Current velocity plays a dual role: velocities of 20 to 40 cm/s enhance nutrient renewal and reduce epiphyte attachment, whereas velocities below 5 cm/s promote epiphyte overgrowth and velocities above 40 cm/s cause thallus breakage (Cokrowati *et al.*, 2020; Muzahar *et al.*, 2025). Cultivation depth is also a critical factor, as light attenuation reduces photosynthesis at depths below 20 cm or greater than 50 cm (Kasnir *et al.*, 2023; Pong-Masak and Sarira, 2020).

Seedling Quality

Seedling quality is a decisive factor in early-phase productivity, independent of the cultivation method used. Tissue-cultured seedlings have been shown to produce significantly higher absolute growth compared to conventional local seedlings, largely due to their pathogen-free status, higher meristematic activity, and uniform size (Cokrowati *et al.*, 2020; Rachmawati and Abdillah, 2019). Strain selection also plays a role, as demonstrated by the superior performance of the Maumere strain over the Tembalang strain under identical cultivation conditions (Zainuddin and Rusdani, 2018). These findings suggest that even the most technically advanced cultivation system will underperform if inferior planting material is used.

Conceptual Framework and Research Contribution

The literature reviewed above reveals that the productivity of *K. alvarezii* is determined by a complex interaction among cultivation method, environmental conditions, and seedling quality. However, no single study has systematically synthesized these three dimensions within a unified comparative framework. This gap underscores the need for a systematic review that integrates findings across multiple studies and locations, which forms the conceptual basis of the present research.

The novelty of this study lies in its systematic and integrative approach to comparing longline and floating raft cultivation methods for *Kappaphycus alvarezii* by simultaneously synthesizing biological, environmental, and economic performance data from peer-reviewed literature published between 2017 and 2026. Unlike prior studies that examined individual variables or single methods in isolation, this review provides a multi-dimensional evidence base that can directly inform site-specific method selection for farmers and aquaculture policymakers in Indonesia.

METHODOLOGY

This study employs a *systematic review* approach to analyze the performance of *Kappaphycus alvarezii* seaweed cultivation systems by comparing the longline and floating raft methods. Data were collected from scientific articles indexed in reputable databases published between 2017 and 2026 to ensure relevance to current developments. The literature search was conducted using a combination of keywords in Indonesian and English, such as *"Kappaphycus alvarezii* longline cultivation," *"floating raft seaweed farming*," and *"seaweed growth* performance" to obtain specific results. Inclusion criteria included articles discussing the cultivation of *Kappaphycus alvarezii* using longline and/or floating raft methods and presenting quantitative data on growth, while irrelevant articles, those lacking empirical data, or those from non-reputable sources were excluded from the analysis.

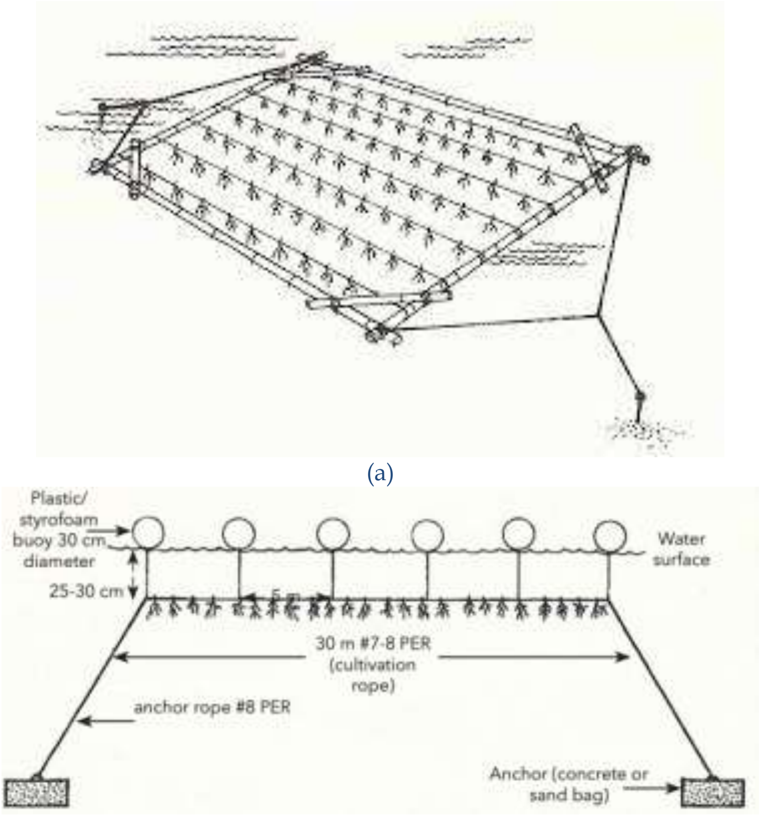
The cultivation methods analyzed focused on longline and floating raft systems, where the longline method uses a main line stretched horizontally with the aid of buoys and anchors so that the plants hang and follow current dynamics, while the floating raft method uses a floating frame structure that keeps the plants in a more stable position in the water column. Article selection was conducted in stages through identification, screening, eligibility assessment, and inclusion following the PRISMA flowchart. Extracted data included author information, aquaculture methods, growth parameters such as biomass, specific growth rate, daily growth rate, and absolute growth rate, environmental conditions such as temperature, salinity, current, and other water quality parameters, as well as economic aspects where available. All data were then analyzed descriptively and comparatively through narrative synthesis and tabular presentation to identify patterns, performance differences, and relationships between cultivation methods, environmental conditions, and seaweed productivity.

RESULTS

Seaweed Cultivation Methods

Kappaphycus alvarezii is a red seaweed (*Rhodophyta*) of the Solieriaceae family that is the primary source of carrageenan and is one of the most widely cultivated macroalgae in the world (Rudke *et al.,* 2020). Since the 1970s, its cultivation has been carried out through effective vegetative clonal propagation, which maintains superior traits but reduces genetic diversity, making it more vulnerable to environmental conditions, pests, and diseases. Therefore, the development of new cultivars through the collection of wild individuals and selective breeding is necessary to ensure the sustainability of cultivation (Roleda *et al.,* 2024). Morphologically, this species has straight, cylindrical, branching stolons without spines and is capable of rapid growth, doubling its biomass within 15–30 days.

The growth of *Kappaphycus alvarezii* is influenced by environmental factors, particularly temperature, light, and nutrients. The optimal temperature range is 27–30°C, with the highest growth rate at 29°C, while high temperatures can significantly reduce growth (Oedjoe *et al.,* 2022). Light intensity and the availability of nutrients such as nitrate and phosphate also play a role in increasing biomass and growth rates (Barille *et al.,* 2024). This species typically inhabits shallow tropical marine waters with suitable light, current, and depth conditions to support optimal growth (Aris and Labenua, 2020). The two main cultivation methods compared in this study are illustrated in Figure 1.



(a)

(b)

Figure 1. Seaweed Cultivation (a) Floating Raft Method (b) Longline Method.
Source: SEAFDEC Aquaculture Department (2017)

The longline and floating raft methods are two commonly used cultivation systems for *Kappaphycus alvarezii* and have distinct technical characteristics. The longline method uses a main line stretched horizontally across the water surface with seedlings tied to branch lines (Afandi dan Syam 2020). This system is relatively simple, easy to implement, and uses readily available materials, making it widely adopted by aquaculturists. In contrast, the floating raft method employs bamboo or wooden structures that are floated and anchored, providing greater stability on the water surface (Masak and Sarira, 2016). Table 1 summarizes the key differences in principles, advantages, and disadvantages between the longline and floating raft cultivation systems.

Table 1. Differences in the Cultivation Aspects of Longline and Floating Raft Seaweed Farming

Cultivation System	Principle	Advantages	Disadvantages	References
Long-line	The main line is stretched horizontally near the surface (0–50 cm), with seedlings tied to vertical or horizontal risers.	Water and nutrient circulation are smoother due to minimal resistance. Maximum sunlight exposure (optimal photosynthesis). Construction costs are relatively low and the system is easy to repair.	Vulnerable to attacks by herbivorous fish (due to lack of protection). Low stability in strong waves /currents; the support structure is prone to breaking. Growth may be lower than in enclosed systems if pest pressure is high.	Kasim and Mustafa (2017); Patadjai *et al.* (2024); Husniah *et al.* (2020); Cokrowati *et al.* (2020)
Floating Raft	Seedlings are planted on nets or ropes attached to bamboo/HDPE rafts floating on the surface.	Better stability, protected from large waves. Can be combined with safety nets (floating cages) to prevent pests. Yield per unit area can be higher (especially with vertical farming).	Construction is more expensive and heavier. Water flow can be obstructed beneath the rafts, reducing nutrient supply. Risk of self-shading at high densities.	Wijayanto *et al.* (2011); Rajaram *et al.* (2020); Kasim and Mustafa (2017) – floating cage; Pong-Masak and Sarira (2020) – vertical culture

The main differences between the two methods lie in stability, water flow, and light exposure, which influence seaweed growth. Floating rafts offer greater stability and are more resistant to waves, whereas longlines provide better water circulation and light exposure because they are not obstructed by structures (Masak and Sarira 2016; Afandi dan Syam 2020). These conditions make longlines more likely to produce higher individual growth rates, while floating rafts are superior in total production because they can increase planting density. This is supported by various studies showing that longline systems yield higher growth rates, whereas floating rafts produce greater biomass per unit area (Nugraha *et al.,* 2017; Damayanti *et al.,* 2019; Ateweberhan *et al.,* 2014; Masak and Sarira 2016).

Seaweed Productivity in Various Systems

Growth rate is a key indicator in assessing success. Commonly used parameters include daily growth *rate* (DGR), specific growth *rate* (SGR), and *absolute growth rate* (AGR). Growth is influenced by internal factors such as species, strain, thallus age, and seedling origin as well as external factors such as temperature, salinity, current, light, nutrients, and cultivation methods.

The specific growth rate and/or daily growth rate values from the synthesis show a wide range, ranging from 0.02% per day to 8.4% per day. The lowest value was obtained in a study by Husniah et al. (2020) in Mandar Bay, namely 0.02%/day, while the highest value was achieved by Nisa et al. (2024) in Bali during the early phase of cultivation, namely 8.4% per day before experiencing a decline. Most studies indicate a growth range of 3–6% per day, which is considered optimal as it exceeds the minimum threshold of 3% per day for a profitable operation (Anggadiredja *et al.,* 2006; Ask and Azanza, 2002). Total biomass also varies depending on the location and seaweed cultivation method used, with the highest production reaching 2,819 g/m of rope in Bontang (Simatupang *et al.,* 2021), while the lowest production ranged from 495–848 g/m at several other locations. Absolute growth values also vary from 8.2 g to 2,675 g, indicating that production yields are significantly influenced by a combination of environmental factors and cultivation techniques. A detailed comparison of growth rates, biomass, and key findings from various studies is presented in Table 2.

Table 2. Comparison of *Kappaphycus alvarezii* Seaweed Growth

Author and year	Location	Method	DGR / SGR (%/day)	Biomass (g/m² or kg)	Main results
Cokrowati *et al.,* (2020)	Seriweh, East Lombok	Longline (tissue culture seedlings)	Not calculated (absolute growth 451.43 g/45 days)	–	Tissue-cultured seedlings grew faster (451.43 g) than local seedlings (169.29 g).
Husniah *et al.,* (2020)	Mandar Bay, West Sulawesi	Longline (planting distance 15–60 cm)	SGR = 0.14%/week (≈0.02%/day) – very low	Highest absolute growth: 165 g (45 cm spacing)	A spacing of 45 cm yields the best absolute growth and SGR.
Kasim and Mustafa (2017)	Bau-Bau, Southeast Sulawesi	Longline vs. floating cage	Longline: 2.43%/day (August); Floating cage: 3.69%/day	Longline: 22.5 kg/40 days (starting at 5 kg); Cage: 38.8 kg	Floating cages are better because they protect against herbivorous fish; 40% of the longline's line was damaged.
Kasnir *et al.,* (2023)	Palette, South Sulawesi	Longline (depth 1.5–4 m)	SGR = 3.0%/day (depth 1.5 m)	Production 1,208 g/m² (depth 1.5 m)	Depth of 1.5 m is optimal; growth decreases at greater depths due to reduced light.
Muzahar *et al.,* (2025)	Pelakak Village, Lingga, Riau Islands	Longline	Green K. alvarezii: 0.55%/day; K. striatus: 0.31%/day	Final absolute weight ≈ 156–210 g (initial 100 g)	Green K. alvarezii is more adaptive; high currents cause talus damage and ice-ice disease.
Nisa *et al.,* (2024)	PT Sea Six Energy, Bali	Longline	K. alvarezii: 8.4% /day (first 2 weeks), decreasing to 4.8%/day (end)	Total weight 1,348.5 kg (51 days) for K. alvarezii	SGR decreased drastically over time; no significant difference from E. spinosum.
Patadjai *et al.,* (2024)	Bone-bone, Baubau	Longline vs. horinet	Longline: 0.95%/day; Horinet: 3.08%/day	Absolute growth: longline: 8.2 g; horinet: 40.5 g	Horinet (horizontal net) protects against pests, resulting in

					significantly better growth.
Pong-Masak and Sarira (2020)	Central Buton, Southeast Sulawesi	Verticulture (floating rafts with vertical nets)	DGR: 5.6%/day (depth 0.2 m) to 2.2%/day (5 m)	–	Depths of 0.2–3 m provide optimal growth; carrageenan is not affected by depth.
Rachmawati and Abdillah (2019)	Lampung Marine Aquaculture Research and Development Center	Framed longline (floating raft with frame)	Daily growth rate 4.85%/day (week 4)	Absolute growth 138.61 g (30 days, starting at 50 g)	Tissue-cultured seedlings exhibit a higher growth rate than conventional seedlings.
Rajaram *et al.*, (2020)	Palk Bay, India	Floating raft (bamboo)	DGR: 3.2–4.0%/day (highest 4.0% in November–December)	Crop yield: 330–491 kg FW/raft (45 days)	Seaweed growth reduces plankton and benthos at the cultivation site (nutrient competition).
Setiawan *et al.*, (2023)	Bungin Permai, Southeast Sulawesi	Longline (co-culture with Sargassum)	K. alvarezii (initial weight 10 g): 5.3–7.8%/day	–	An initial weight of 10 g yielded the highest DGR; Sargassum thalli were more prone to breaking.
Simatupang *et al.*, (2021)	10 locations in Indonesia (Bontang, Mamuju, etc.)	Longline (45-day standard)	Not included (biomass production only)	Highest production: Bontang 2,819 g/m; lowest: 495–848 g/m	Production varies greatly between locations; carrageenan quality also varies (8.6–26.4%).
Tindage *et al.*, (2022)	Nain Island, North Sulawesi	Vertical culture with string lines (depths of 0, 50, 100 cm)	GFR: 6.77% (0 cm), 6.79% (50 cm), 6.55% (100 cm)	Absolute growth: 2,675 g (0 cm), 2,660 g (50 cm), 2,480 g (100 cm)	Depths of 0 and 50 cm yielded equally good growth; growth at a depth of 100 cm decreased significantly.
Zainuddin (2018)	Gerupuk Bay, Lombok	Longline	Daily growth rate ≈ 4–5 %/day (Maumere higher than Tembalang)	–	The Maumere strain performs better than the Tembalang strain.
Wijayanto *et al.*, (2011)	Kalianda, South Lampung,	floating raft vs. longline vs. bottom-set	Growth rate: in floating rafts 48.40%/week (≈6.9%/day)	Highest weight gaining on longline: 122.39 g	on floating rafts showed the highest growth rate and relative growth.
Jasman *et al.*, (2024)	Barru, South Sulawesi	Longline (line stretch vs. circular net)	GIR: longline 4.3–4.5%/day; circular net 2.9–3.3%/day	Absolute growth of the line is higher	Modifications to the round net are less effective because pests (algae, barnacles) inhibit growth.
Mulyani (2026) – review	Various locations	Various systems (longline, tubular net, vertical culture)	Intermediate density (≈50 g/tie) yields an SGR of 3–5%/day	–	Moderate stocking density optimizes growth efficiency and carrageenan quality.
Sri Mulyani and Cahyono (2025)	South Sulawesi	Tie-tie (longline)	SGR: 50 g/tie yields the highest rate (no specific figure provided)	Highest biomass at 75 g/tie	There is a trade-off between growth and carbon stability.

Nursidi *et al.,* (2020)	South Sulawesi	Vertical cultivation (4 columns)	SGR varies between columns (column 2 is the highest)	–	Vertical systems can increase spatial productivity.
Cáceres-Farías *et al.,* (2025)	Ecuador	Tubular net vs. tie-tie (longline)	Tie-tie: 4.0%/day; tubular net: 3.8%/day (no significant difference)	–	Both systems are suitable for use depending on hydrodynamic conditions.

Biomass production also varies by location and method. The highest value was reported by Simatupang et al. (2021) in Bontang at 2,819 g/m of line after 45 days of cultivation, while the lowest values ranged from 495–848 g/m and were found in several locations such as Mamuju, Gorontalo, Manado, and Banten. Meanwhile, absolute growth (AGR) ranged from 8.2 g in the longline method (Patadjai *et al.,* 2024) to 2,675 g in the vertical culture method at a depth of 0 cm (Tindage *et al.,* 2022). These differences indicate that productivity is not only influenced by genetic factors but is also heavily determined by environmental conditions and the cultivation techniques employed.

When comparing methods, aquaculture systems that provide physical protection against talus tend to yield higher growth and biomass compared to open longline methods. Modified floating raft methods using nets, such as *floating cages, horinets*, or *tubular nets*, demonstrate better performance. According to research by Kasim and Mustafa (2017), over a 40-day rearing period, the longline method yielded only 22.5 kg from an initial weight of 5 kg, whereas *the floating cage* reached 38.8 kg, with specific growth rates (SGR) of 2.43%/day and 3.69%/day, respectively. Similar results were reported by Patadjai et al. (2024), where the horinet system produced an absolute growth rate of 40.5 g and a specific growth rate of 3.08%/day, significantly higher than *the longline system,* which yielded only 8.2 g and 0.95%/day. Additionally, the vertical culture method also showed good results, as reported by Pong-Masak and Sarira (2020) with a daily growth rate of 5.6%/day at a depth of 0.2 m, and by Tindage et al. (2022) with a daily growth rate of 6.79%/day at a depth of 50 cm.

The conventional longline method can still provide optimal results under suitable environmental conditions. Absolute growth of 451.43 g over 45 days was achieved using tissue-cultured seedlings (Cokrowati *et al.,* 2020), while the daily growth rate reached 4–5%/day for the Maumere strain (Zainuddin, 2018). However, under less favorable environmental conditions, the performance of this method can decline significantly. Excessively strong currents (40–50 cm/s) can cause damage to the talus and inhibit growth (Muzahar *et al.,* 2025), whereas currents that are too weak (0.05–0.12 m/s) trigger the attachment of epiphytes, which hinder the photosynthesis process (Jasman *et al.,* 2024). Therefore, the success of the longline method is highly dependent on the suitability of water conditions at the cultivation site.

Factors in Seaweed Cultivation

Variations in seaweed cultivation yields are influenced by three main factors: environmental conditions, cultivation methods, and seedling quality. These three factors interact to determine growth rates and productivity.

Environmental factors include temperature, salinity, current, light, depth, and season, which directly influence photosynthesis and nutrient uptake.

Environmental conditions exert a strong influence on seaweed growth. Light intensity, which is affected by depth, indicates that at a depth of 1.5 m, the growth rate reaches 3.0% per day and decreases to approximately 1.5% per day at a depth of 4 m due to reduced light (Kasnir *et al.,* 2023). A similar pattern is observed at a depth of 0.2 m, with a growth rate of 5.6% per day, which then decreases to 2.2% per day at a depth of 5 m (Pong-Masak and Sarira, 2020). Seasonal variations also influence growth, with growth rates reaching 4.0% per day during the rainy season due to cooler temperatures and abundant nutrients, then decreasing to 3.2% per day during the dry season when temperatures rise to 35°C (Rajaram *et al.,* 2020).

Water physical and chemical parameters show variation across locations. Water temperature ranges from 26–35°C, with optimal conditions at 27–30°C. Growth rates reach 3.69% per day at temperatures of 25–27°C and decrease at temperatures above 31°C (Kasim and Mustafa, 2017). An increase in temperature from 28°C to 35°C also reduced growth from 4.0% to 3.2% per day (Rajaram *et al.,* 2020). Salinity ranges from 28–37 ppt, with an optimal range of 28–34 ppt. High salinity up to 36.8 ppt can reduce production (Kasnir *et al.,* 2023; Simatupang *et al.,* 2021; Zainuddin, 2018). The optimal current velocity is in the range of 20–40 cm per second. Excessively strong currents can cause damage to the talus and reduce growth by up to 0.55% per day, while excessively weak currents trigger the attachment of epiphytes that inhibit photosynthesis (Kasnir *et al.,* 2023; Muzahar *et al.,* 2025; Jasman *et al.,* 2024).

Cultivation methods influence growth through technical adjustments such as planting systems, protection against disturbances, and planting distances. Protection against herbivores and physical stress improves survival rates; in open longline systems, damage reaches up to 40%, whereas no damage was observed in protected systems (Kasim and Mustafa, 2017; Patadjai *et al.,* 2024). Planting distance is a critical factor as it affects light and nutrient availability as well as the level of competition among plants. A 45 cm planting distance resulted in an absolute growth of 165 g, which was higher than the 15 cm distance at 145 g (Husniah *et al.,* 2020). In the longline system, a planting distance of 25 cm resulted in a growth rate of 6.90% per day and absolute growth of 182.84 g (Ramadan *et al.,* 2022), whereas in the floating raft system, a planting distance of 40 cm yielded the best growth with absolute growth of 98.3 g and a growth rate of 2.3% per day (Ramadhan, 2022). This indicates that differences in current and light conditions in each system influence the optimal planting distance.

Depth is a critical factor directly related to light intensity and environmental stability. In the longline method, depth can be adjusted, making it more flexible. A depth of 20 cm yielded the highest growth of 828 g, while growth decreased at depths of 60 cm and 100 cm (Ndun *et al.,* 2025). This decline occurs due to reduced light, lower temperatures, and weaker currents. Another study showed that a depth of 25 cm resulted in a growth rate of 6.74% per day (Andis *et al.,* 2021). In floating raft systems, plants are generally located in the surface layer, so depth adjustment is more limited. However, depth variation still has an effect, with a depth of 75 cm yielding the highest growth rate, while a depth of 100 cm yields the best carrageenan content (Ramadhan, 2022).

Seedling quality is a determining factor in early productivity. Tissue-cultured seedlings exhibit higher growth compared to local seedlings. Absolute growth reached 451.43 g in tissue-cultured seedlings and only 169.29 g in conventional seedlings. Strain differences also affect yields, with strains having younger thalli and being pathogen-free exhibiting higher growth rates because energy is more focused on cell division (Cokrowati *et al.,* 2020; Zainuddin, 2018; Mulyani, 2026).

A comparison between the longline and floating raft methods shows that both systems have different advantages. The longline system yields a higher daily growth rate of 6.97% compared to 4.38% for the floating raft, while the floating raft yields higher productivity of 1,900 kg per cycle compared to 202 kg for the longline due to more optimal space utilization (Pong-Masak and Sarira, 2016). Another study showed that the longline system produced the highest absolute growth of up to 217.09 g per clump, while negative growth was observed in the floating raft system (Nasrudin, 2022). However, under certain conditions, the floating raft system can yield the best results (Ikhsan *et al.,* 2022). Overall, seaweed cultivation outcomes result from a complex interaction between environmental factors, cultivation methods, and seedling quality. Extremely low growth values may occur due to unsuitable environmental conditions or differences in calculation methods, whereas high values generally occur in the early phase under optimal conditions. Therefore, the selection of cultivation methods must be adapted to water conditions such as season, current, and depth to achieve more optimal results.

DISCUSSION

The findings of this systematic review demonstrate that the productivity of *Kappaphycus alvarezii* cultivation is not determined by a single factor but by the complex interaction between environmental conditions, cultivation methods, and seedling quality. One of the most consistent patterns observed is that aquaculture systems offering physical protection against herbivorous fish and wave action, such as floating cages, horinets, and tubular nets, consistently outperform open longline systems in terms of total biomass production and survival rates. This superiority can be explained by the reduction in thallus grazing and mechanical breakage, which are common in unprotected systems, particularly during strong currents or high pest abundance. In contrast, the longline method tends to yield higher individual growth rates when environmental conditions are favorable, largely due to its open structure that allows unobstructed water flow and maximum sunlight exposure. However, these advantages are quickly diminished under suboptimal conditions such as high wave energy or heavy herbivory, making longline a site-dependent option rather than a universally superior method.

Depth and light availability emerged as critical modulators of growth. The highest daily growth rates were consistently recorded at depths between 0 and 50 cm, where light intensity is maximal. Deeper than 4 meters, light attenuation becomes severe, reducing photosynthesis and thus growth. This pattern aligns with the known photophysiology of *Kappaphycus alvarezii*, which requires high irradiance for optimal carbon fixation. Similarly, current velocity showed a bimodal effect: velocities around 20–40 cm/s enhance nutrient renewal and prevent epiphyte attachment, whereas velocities above 40 cm/s cause thallus damage and below 5 cm/s promote epiphyte overgrowth. These thresholds explain why some studies reported poor longline performance even in otherwise suitable locations. Seasonal variation further complicates the picture, as higher temperatures during the dry season increase respiration costs and oxidative stress, leading to lower net growth despite abundant light.

Seedling quality proved to be a decisive factor independent of the cultivation method. Tissue-cultured seedlings exhibited substantially higher absolute growth than conventional local seedlings, which is attributable to their pathogen-free status, higher meristematic activity, and uniform size that reduces intraspecific competition. The choice of strain also matters, as shown by the superior performance of the Maumere strain over the Tembalang strain. Therefore, even the most advanced cultivation system will underperform if inferior seedlings are used. Taken together, the evidence supports the view that optimal seaweed farming requires a holistic approach where method selection, site evaluation, and seedling quality are jointly optimized rather than treated in isolation.

CONCLUSIONS AND RECOMMENDATIONS

The results indicate that neither cultivation method can be considered universally superior, as performance is strongly influenced by environmental conditions, cultivation design, and seedling quality. In terms of growth performance, the longline system generally produced higher individual daily growth rates under favorable environmental conditions characterized by adequate water movement and low herbivore pressure. In contrast, modified floating raft systems, including floating cages, horinets, and tubular nets, consistently generated higher total biomass production and survival rates because they provided greater protection against thallus damage and grazing pressure.

The review also identified several environmental factors that play a crucial role in determining cultivation success. Water depth ranging from 20 to 50 cm, current velocity between 20 and 40 cm/s, and temperatures of 27–30°C were consistently associated with optimal growth across both cultivation systems. In addition, seedling quality emerged as a key determinant of productivity, with tissue-cultured seedlings demonstrating superior growth performance compared with conventional local seedlings regardless of the cultivation method employed. These findings highlight the importance of adopting a site-specific and integrated management approach in which cultivation method, environmental suitability, and seedling quality are considered simultaneously. Based on the evidence synthesized in this review, the use of floating raft systems equipped with protective netting and supported by tissue-cultured seedlings is recommended as an effective strategy for improving the productivity, resilience, and long-term sustainability of *Kappaphycus alvarezii* aquaculture.

Farmers should select cultivation methods based on local environmental conditions. In sheltered areas with low wave action and minimal herbivores, the longline method is cost-effective and yields high individual growth, especially at depths of 20–50 cm and planting distances of 25–45 cm. In exposed coastal areas with strong currents or high pest pressure, floating raft systems with protective nets (e.g., floating cages or horinets) are recommended despite higher costs, as they produce greater total biomass and reduce thallus loss. Regardless of method, farmers should use tissue-cultured seedlings from high-growth strains and avoid sites with extreme currents (<5 cm/s or >40 cm/s) or temperatures above 31°C.

FURTHER STUDY

Future research should address the lack of long-term (≥6 months) field experiments, standardize growth parameter reporting, and include economic analyses such as cost-benefit ratios. The interactive effects of climate change (rising temperature, ocean acidification) on method-specific performance need investigation. Comparative studies across different Indonesian regions using identical experimental designs would also help generate location-specific recommendations for resilient and profitable seaweed farming.

ACKNOWLEDGMENT

The author would like to express their deepest gratitude to thanks the Rector of Padjadjaran University for providing access to *the E-Library*, which facilitated literature searches during the writing of this article. The author also extends gratitude to all researchers and academics whose scientific works served as references in this *systematic review*.

REFERENCES

Afandi, A., & Syam, A. (2020). Analisis kuantitas tiga varietas rumput laut Kappaphycus alvarezii yang dibudidaya dengan metode long line. *Jurnal Akuakultura Universitas Teuku Umar*, *2*(2). https://doi.org/10.35308/ja.v2i2.1592

Andis, A., Irawan, H., Wulandari, R. (2022). The Effect of Depth on the Growth of Seaweed *Kappaphycus alvarezii* using Longline Method. *Jurnal Intek Akuakultur*, *5*(2), 25-35. https://doi.org/10.31629/intek.v5i2.3091

Anggadiredja, J. T., Zatnika, A., Purwoto, H., & Istini, S. (2006). *Rumput laut: Pembudidayaan, pengolahan, dan pemasaran komoditas perikanan potensial*. Penebar Swadaya.

Aris, M., & Labenua, R. (2020). Horizontal transmission of ice-ice disease in seaweed Kappaphycus alvarezii (Doty) LM Liao (Gigartinales, Rhodophyta). *Hidrobiológica*, *30*(2), 155-161. https://doi.org/10.24275/uam/izt/dcbs/hidro/2020v30n2/muhammad

Ask, E. I., & Azanza, R. V. (2002). Advances in cultivation technology of commercial eucheumatoid species: A review with suggestions for future research. *Aquaculture*, 206(3–4), 257–277. https://doi.org/10.1016/S0044-8486(01)00724-4

Ateweberhan, M., Rougier, A., & Rakotomahazo, C. (2014). Influence of environmental factors and farming technique on growth and health of *Kappaphycus alvarezii* (cottonii) cultivated in southwest Madagascar. *Journal of Applied Phycology*. https://doi.org/10.1007/s10811-014-0378-3

Barillé, L., Paterson, I. L., Oiry, S., Aris, A., Cook-Cottier, E. J., & Nurdin, N. (2025). Variability of *Kappaphycus alvarezii* cultivation in South-Sulawesi (Indonesia) related to the monsoon shift: Water quality, growth and colour quantification. *Aquaculture Reports*, *40*, 102557. https://doi.org/10.1016/j.aqrep.2024.102557

Budiyanto, Kasim, M., & Abadi, S. Y. (2019). Growth and carrageenan content of local and tissue culture seed of *Kappaphycus alvarezii* cultivated in floating cage. *AACL Bioflux*, 12(1), 167–178.

Cáceres-Farias, L., Montúfar-Romero, M., Lodeiros, C. *et al.* Growth rate comparison of three *Kappaphycus alvarezii* colour strains cultivated using tubular netting and tie-tie methods in the waters of Ecuador. *J Appl Phycol* **37**, 1139–1152 (2025). https://doi.org/10.1007/s10811-025-03465-5

Cokrowati, N., Diniarti, N., Setyowati, D. N., & Mukhlis, A. (2020). Pertumbuhan rumput laut lokal dan rumput laut hasil kultur jaringan *Kappaphycus alvarezii*. *Journal of Fisheries and Marine Research*, 4(1), 62–65. https://doi.org/10.21776/ub.jfmr.2020.004.01.9

Damayanti, T., Aryawaty, R., & Fauziyah, F. (2019). Laju pertumbuhan rumput laut *Eucheuma cottonii* (*Kappaphycus alvarezi*) dengan bobot bibit awal berbeda menggunakan metode rakit apung dan long line di perairan Teluk Hurun, Lampung. *Maspari Journal*, 11(1).

Asni, A. (2015). Analisis poduksi rumput laut (Kappaphycus alvarezii) berdasarkan musim dan jarak lokasi budidaya di perairan kabupaten bantaeng. *Jurnal Akuatika Indonesia*, *6*(2), 140-153.

Hardan, Warsidah, & Nurdiansyah, S. I. (2020). Laju pertumbuhan rumput laut *Kappaphycus alvarezii* dengan metode penanaman yang berbeda di perairan laut Desa Sepempang, Kabupaten Natuna. *Jurnal Laut Khatulistiwa*, 3(1), 14–22. https://doi.org/10.26418/lkuntan.v3i1.35101

Husniah, Nur, M., Tenriware, Tamaruddin, A., Jabbar, F. B. A., & Tambaru, R. (2020). Growth performance of seaweed *Kappaphycus alvarezii* in different planting distance using long-line farming, Mandar Bay, West Sulawesi Indonesia. *IOP Conference Series: Earth and Environmental Science*, 575, 012097. doi :10.1088/1755-1315/575/1/012097

Ikhsan, F., Irawan, H., dan Wulandari, R. (2022). Laju Pertumbuhan Rumput Laut *Kappaphycus alvarezii* Varietas Hijau dan Coklat pada Metode Budidaya yang Berbeda. *Jurnal Intek Akuakultur*, *6*(1), 83-91. https://ojs.umrah.ac.id/index.php/intek/article/view/4054

Jasman, A., Rusdi, R., Malik, A. A., Sahabuddin, & Yushra. (2024). Analisis perbandingan produksi budidaya rumput laut (*Eucheuma spinosum*) metode longline menggunakan bentangan tali dan bentangan jaring bundar. *Jurnal Ilmiah AgriSains*, 25(2), 71–79.

Kasim, M., & Asnani. (2017). Penentuan musim reproduksi generatif dan preferensi perekatan spora rumput laut *Eucheuma cottonii*. *Ilmu Kelautan*, 17(4), 209–216. https://doi.org/10.14710/ik.ijms.17.4.209-216

Kasim, M., & Mustafa, A. (2017). Comparison growth of *Kappaphycus alvarezii* (Rhodophyta, Solieriaceae) cultivation in floating cage and longline in Indonesia. *Aquaculture Reports*, 6, 49–55. https://doi.org/10.1016/j.aqrep.2017.03.004

Kasnir, M., Syarifuddin, & Nisaa, K. (2023). The effect of depth on the growth and productivity of seaweed *Kappaphycus alvarezii* using long-line method. *Akuatikisle: Jurnal Akuakultur, Pesisir dan Pulau-Pulau Kecil*, 7(2), 139–143.

Mulyani, S. (2025). Assessing the global cultivation practices of *Kappaphycus alvarezii*: A comprehensive review of growth dynamics, nutrient management, and biochemical composition. *Jurnal Riset Diwa Bahari (JRDB)*, 3(2), 100–109.

Mulyani, S. (2026). Optimizing planting density and culture systems in *Kappaphycus alvarezii*: A systematic review of growth, carbon dynamics, and carrageenan quality. *Bosowa Journal of Biological Sciences*, 6(1), 1–15. https://doi.org/10.32996/bjbs.2026.6.1.2

Mulyani, S., & Cahyono, I. (2025). Growth dynamics and carbon content during red seaweed (*Kappaphycus alvarezii*) cultivation. *Egyptian Journal of Aquatic Biology and Fisheries*, 29(3), 1907–1921.

Muzahar, Said Raza'i, T., Viruly, L., Wulandari, R., Miranti, S., Putri, D. S., Yulianto, T., Bakkara, O. R., Irawan, H., Sinaga, D., Nasmi, J., Andia, B., Saputra, R., Bahri, S., Lovina, R., Darmawan, D., & Syafiq, R. M. (2025). Perbandingan pertumbuhan rumput laut *Kappaphycus striatus* dan *Kappaphycus alvarezii* varietas hijau pada metode longline. *Acta Aquatica: Aquatic Sciences Journal*, 12(3), 278–283. https://doi.org/10.29103/aa.v12i3.21565

Nasrudin, N. (2022). *Perbandingan Pertumbuhan Rumput Laut (Eucheuma Cottoni) Dengan Menggunakan Metode Rakit Jaring Apung Dan Longline Vertikal*. Skripsi, Universitas Tadulako.

Ndun, K., Linggi, Y., & Tobuku, R. (2025). Perbandingan Pertumbuhan Rumput Laut (*Kappaphycus alvarezii*) Yang Dipelihara Pada Kedalaman Berbeda Di Perairan Teluk Rote. *Jurnal Aquatik*, *8*(1), 91-100. https://doi.org/10.35508/jaqu.v8i1.23529

Nisa, A. C., Jatayu, D., & Alfiani, P. P. (2024). Growth performances and productivities of *Kappaphycus alvarezii* and *Eucheuma spinosum* cultivated with long-line method in PT. Sea Six Energy Indonesia. *Journal of Aquaculture and Fish Health*, 13(3), 388–396. doi : 10.20473/jafh.v13i3.53831

Nugraha, S., Affandi, R., & Imran, Z. (2017). *Pertumbuhan rumput laut Kappaphycus alvarezii (Doty 1988) menggunakan model penanaman berbeda di Pulau Burung, Kepulauan Seribu Jakarta* [Skripsi]. Bogor Agricultural University (IPB).

Nursidi, Mauli, & Heriansah. (2020). Development of seaweed *Kappaphycus alvarezii* cultivation through vertical method in the water of small islands in South Sulawesi, Indonesia. *AACL Bioflux*, 13(6), 1428–1435.

Oedjoe, M. D. R., Rebhung, F., & Sunadji. (2022). The impact of temperature on growth and carrageenan content of *Kappaphycus alvarezii* in East Nusa Tenggara, Indonesia. *AACL Bioflux*, 15(3), 1570–1577. https://doi.org/10.21203/rs.3.rs-1601122/v1

Patadjai, R. S., Kasim, M., & Pratama, M. R. (2024). Comparison of growth rate of seaweed *Kappaphycus alvarezii* using horizontal net and longline methods. *AACL Bioflux*, 17(4), 1364–1374.

Pong-Masak, P. R., & Sarira, N. H. (2016). Pertumbuhan dan produksi rumput laut *Kappaphycus alvarezii* dengan aplikasi metode vertikultur di Kabupaten Buton Tengah Provinsi Sulawesi Tenggara. *Prosiding Forum Inovasi Teknologi Akuakultur*, 1832.

Pong-Masak, P. R., & Sarira, N. H. (2020). Effect of depth on the growth and carrageenan content of seaweed *Kappaphycus alvarezii* cultivated using verticulture method. *IOP Conference Series: Earth and Environmental Science*, 575, 012096. https://doi.org/10.1051/e3sconf/202014701011

Rachmawati, S., & Abdillah, A. A. (2019). Studi pertumbuhan bibit rumput laut (*Kappaphycus alvarezii*) hasil kultur jaringan dengan metode longline berbingkai di Balai Besar Perikanan Budidaya Laut Lampung. *Journal of Marine and Coastal Science*, 8(1), 1–9. https://doi.org/10.30587/jpp.v2i1.805

Rajaram, R., Rameshumar, S., Paray, B. A., & Albeshr, M. F. (2020). Impacts of cultivation of red algae *Kappaphycus alvarezii* on planktonic and benthic faunal density in relation to environmental and hydrological parameters in tropical coastal ecosystem. *Acta Ecologica Sinica*, 40(6), 1–11. https://doi.org/10.1016/j.chnaes.2020.11.006

Ramadan, R., Irawan, H., Wulandari, R. (2022). Pengaruh Jarak Tanam yang Berbeda terhadap Pertumbuhan Rumput Laut *Kappaphycus alvarezii* Mengunakan Metode Longline. *Jurnal Intek Akuakultur*, 6(1), 92-102. https://doi.org/10.31629/intek.v6i1.3644

Ramadhan, Sahrul. (2022). *Pengaruh Jarak Tanam dan Kedalaman Terhadap Budidaya Rumput Laut Kappaphycus alvarezii dengan Metode Kombinasi Rakit Apung.* Skripsi, Universitas Mataram.

Rasniyad, N., Kasim, M., & Balubi, A. M. (2021). Genetic diversity and growth performance of *Kappaphycus alvarezii* from different origins in Southeast Sulawesi. *IOP Conference Series: Earth and Environmental Science*, 860, 012045.

Roleda, M. Y., Hinaloc, L. A. R., Capacio, I. T., Jao, M. C. B., & Crisostomo, B. A. (2024). Reproductive biology and novel cultivar development of the eucheumatoid *Kappaphycus alvarezii*. In *Tropical Phyconomy Coalition Development* (pp. 45–68). Springer.

Rudke, A. R., de Andrade, C. J., & Ferreira, S. R. S. (2020). *Kappaphycus alvarezii* macroalgae: An updated review on its biotechnological potential. *Algal Research*, 52, 102109. https://doi.org/10.1016/j.tifs.2020.07.018

SEAFDEC Aquaculture Department. (2017). Seaweed *Kappaphycus* farming [Brochure]. Tigbauan, Iloilo, Philippines: Author.

Setiawan, L. O. M. A., Iba, W., & Patadjai, R. S. (2023). Growth of seaweed *Kappaphycus alvarezii* co-cultivated with *Sargassum plagiophyllum* using low initial seed weights in longline method. *IOP Conference Series: Earth and Environmental Science*, 1241, 012124. Doi.org/10.1088/1755-1315/1241/1/012124

Simatupang, N. F., Pong-Masak, P. R., Ratnawati, P., Agusman, Paul, N. A., & Rimmer, M. A. (2021). Growth and product quality of the seaweed *Kappaphycus alvarezii* from different farming locations in Indonesia. *Aquaculture Reports*, 20, 100685. https://doi.org/10.1016/j.aqrep.2021.100685

Tindage, T. W., Ngangi, E. L. A., Kreckhoff, R. L., Mudeng, J. D., & Sambali, H. (2022). Pertumbuhan rumput laut *Kappaphycus alvarezii* yang menggunakan tali ris senar secara vertikultur. *Budidaya Perairan*, 10(2), 128–133.

Widiastuti, S. (2007). Kadar karagenan rumput laut *Eucheuma cottonii* strain Maumere dan Tembalang pada beberapa umur panen di Muluk Lombok Tengah. *Agroteksos*, 17(2), 123–128.

Wijayanto, T., Hendri, M., & Aryawati, R. (2011). Studi pertumbuhan rumput laut *Eucheuma cottonii* dengan berbagai metode penanaman yang berbeda di Perairan Kalianda, Lampung Selatan. *Maspari Journal*, 3(1), 51–57.

Wulandari, S. A. (2023). Determining cultivation methods based on seaweed quality (*Kappaphycus alvarezii*) in Sumenep Regency. *Journal of Science Education and Application*, 5(1), 1–15.

Zainuddin, F., & Rusdani, M. M. (2018). Performa rumput laut *Kappaphycus alvarezii* dari Maumere dan Tembalang pada budidaya sistem longline. *Jurnal Mina Laut Indonesia*, 4(1), 17–28.