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Tropical Phyconomy Coalition Development

Focus on Eucheumatoid Seaweeds

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Preface

At the time of writing, farmed, red macroalgae, particularly of the genera *Eucheuma* and *Kappaphycus* (collectively referred to as the eucheumatoid seaweeds), provide the raw material foundation for sea vegetable, carrageenan, and agricultural, nutrient value chains that yield leading marine products' exports for Indonesia and the Philippines. The eucheumatoids are also a basis for substantial Chinese seaweed products manufacturing. In addition, several tropical jurisdictions around the world produce eucheumatoid seaweeds and aspire to build value chains based on their cultivation.

By 2020, it was evident to the founders of Phyconomy.org that the development of phyconomy for eucheumatoid seaweeds would benefit from increased collaboration among researchers of the global phyconomist community. That led to creation of the Tropical Phyconomy Collaboration Development's (Phyconomy.org) first eucheumatoid seaweeds biology webinar on July 7–8, 2021 (a.k.a. TPCD-1).

For the TPCD-1 webinar, the website Phyconomy.org was created and an accessible repository of more than 40 video presentations with textual abstracts was made available online so webinar presenters, attendees, and the public could view and read content at their convenience and interact with presenters through a linked, online forum. During the July 7–8 webinar, presenters responded to questions from attendees, and the webinar was recorded for retention as online, website content.

This work complements TPCD-1 online material with a hard-copy book. The chapters of this book were written not only to preserve TPCD-1 content in printed form but also to present further development of thinking based on lessons learned during the webinar. Some of this material indicates the direction in which collaboration has moved since TPCD-1, and at the time of writing, a TPCD-2 was in preparation with intent to move tropical phyconomy collaboration toward tangible actions.

Bali, Indonesia — Iain Charles Neish

Contents

22 Novel Methods for Protecting *Kappaphycus alvarezii* from Herbivores: An Overview of Development and Economic Prospects

Ma'ruf Kasim, La Sara, Nurdiana, Ernaningsih, Andi Tamsil, Wardha Jalil, Tamar Mustari, and Mudian Paena

Abstract

Kappahycus alvarezii is widely cultivated by Indonesian people living in coastal areas. The use of simple cultivation methods and low investment in *K. alvarezii* cultivation has encouraged an increase in the number of seaweed farmers. Farmers mainly use the longline method of seaweed cultivation. One of the most severe problems seaweed farmers face is the attack of fish and turtle pests. Such attacks are associated with the longline method, which is an open method that provides opportunities for grazing of the seaweed crop by fish and turtles. Confinement innovation is urgently needed to protect seaweed from consumption by various fish and turtles. In 2018, cage innovations were developed and tested with various variants, including horizontal net (Horinet), vertical net (Vertinet), long net, and basket net. This chapter explored the technical effectiveness and economic feasibility of using Horinet and Vertinet. The results showed that the growth of *K. alvarezii* on the Horinet, Vertinet, and longline was 5.0, 4.6, and 4.2%/day, respectively. Economic analysis of the Horinet and Vertinet systems indicated that their implementation in seaweed cultivation shows economic feasibility. From the value of the revenue/cost (R/C) ratio and other economic feasibility indices, the Horinet and Vertinet methods seemed to be feasible for commercial development as effective solutions for protecting seaweed crops from fish and turtle pests.

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Keywords

Horizontal net · Vertical net · Longline · Seaweed · *Siganus* sp.

22.1 Introduction

Indonesia is one of the countries with the largest *Kappaphycus alvarezii* production in the world (Langford et al. 2022). Seaweed production in Indonesia is mostly based on cultivation because the carrying capacity of coastal waters for cultivation is excellent and comprehensive. Indonesia's seaweed cultivation area has been estimated at 6,846,800 km (BPS 2021). This coastal area produces seaweed species for export commodities, including *Gracilaria* sp. and *K. alvarezii*. Several Indonesian regions have cultivated seaweed, including the provinces of Bali, Lampung, West Nusa Tenggara, East Nusa Tenggara, Riau, Sulawesi, and Maluku (Kasim et al. 2022). Seaweed farming in Indonesia commenced with local cultivars of *Eucheuma denticulatum*, but *Kappaphycus* seaweed farmed in Indonesia was initially imported from the Philippines and known as the Tambalang strain. Experimental growth of this strain showed that it could be propagated through cultivation (Hurtado and Agbayani 2000). Eventually, the most widely cultivated species of eucheumatoid seaweeds farmed in Indonesia were *K. alvarezii*, *E. striatus*, and *E. denticulatum* (Sulu et al. 2004). These species have been widely cultivated in several countries, including the Philippines, where they have been commercially farmed since 1971 (Doty and Alvarez 1975). Cultivated eucheumatoid seaweed production increased rapidly following initial cultivation successes in 1971, with an initial biomass of less than 1000 tonnes dry weight increasing to 100,000 tonnes dry weight within a few years (Doty and Alvarez 1975). Two countries in Southeast Asia where *K. alvarezii* is intensely cultivated are the Philippines and Indonesia (Dawes 1998). Coastal communities in several other tropical countries in Southeast Asia also cultivated

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K. alvarezii with high production. Each country has several commonly used cultivation techniques. However, the most commonly applied cultivation systems include longlines, raft systems, and off-bottom and on-bottom systems. The long-line cultivation method and other methods are simple methods of tying seaweed on ropes to be cultivated for up to 40 days before harvesting (Kasim et al. 2019). However, the seaweed industry continues to face various problems. One of the serious problems in seaweed cultivation using open methods is the attack of herbivorous fish pests (Kasim and Mustafa 2017; Kasim et al. 2017). For example, seaweed cultivation areas in Mediterranean coastal waters have experienced an increase in herbivore fish populations correlated with the advance of certain invasive macroalgal species (Tomas et al. 2011). In India, especially on Krusadai Island, seaweed cultivation, such as *K. alvarezii* and *E. denticulatum*, has experienced decreased production by at least 10% due to predatory pests such as *Siganus javus* (Rabbitfish), *Acanthurus* sp. (surgeon fish), *Cetoscarus* sp. (Parrotfish) and sea urchin *Tripneustes* sp. (Ganesan et al. 2006). The development of seaweed cultivation methods is still very slow; since 1980, people in Southeast Asia and Indonesia have continued to use the longline cultivation method (Adnan and Porse 1987; Luxton 1993; Reis et al. 2015). This is a conventional method and has many drawbacks, including susceptibility to pest attacks and to the emergence of ice-ice syndrome (Kasim and Asnani 2012; Kasim et al. 2016). Herbivorous pest attacks and attachment of epifauna or epiphytes are still commonly observed in cultivated areas in Southeast Asia, which can reduce seaweed production (Ganesan et al. 2006; Johnson and Gopakumar 2011). Even in Indonesia, seaweed production has decreased by up to 60% of the total production per harvest (Kasim et al. 2017). Several countries, such as the Philippines and Brazil, have started to conduct seaweed maintenance efforts to protect seaweed from pests by using traditional bow ropes (Reis et al. 2015; Hurtado-Ponce 1992). Hurtado-Ponce (1992) recommended the cultivation of *K. alvarezii* seaweed in floating cages to prevent the seaweed from being attacked by herbivores. Modification of cultivation with this protection system is dependent on the location's topography and has been implemented in several cultivation areas in the Philippines. The use of cages for cultivating *K. alvarezii* can be carried out in areas with a high intensity of attack by herbivore fish. However, the economic feasibility of tools to support aquaculture needs to be considered. The cultivation of *E. cottoni* with oysters and snapper is an alternative to the caged confinement system (Biswajit et al. 2009). *Gracilaria gracilis* can be cultured in closed containers to avoid attacks by herbivores such as isopods. The floating cage is one of the technological designs that functions as a container for seaweed cultivation, protecting seaweed from grazing while reducing the potential for disease (Kasim 2016). This method has been used by a small number of farmers in Eastern Indonesia, especially in Southeast Sulawesi, to protect seaweed from attacks by herbivorous fish and turtles (Kasim 2016). Various sizes and shapes were developed as tools that can be used for seaweed cultivation. The basic materials of floating cages included PVC pipes and nets equipped with buoys as markers. Weights were used to attach floating rafts to substrates and to make it easier to place the raft at desired locations. The basic material of rafts is designed to form rectangular boxes of varying sizes. The raft surface is left open, the bottom is covered with a multifilament net (mesh size 1 cm), and the sides of the raft are covered with a multifilament net measuring 2 cm (Kasim 2016). During its development, the floating cage underwent several changes and modifications, primarily designed to make it easier for farmers to cultivate seaweed. The sizes and materials used have improved and are cost-effective. This development was based on field tests/topography results at all appropriate topographical levels. Design adjustments were made with suggestions from seaweed farmers. This was done to adjust the habits and effectiveness of using tools for planting and harvesting seaweeds. Several variants of confinement cultivation tools are available for development, including floating net rafts, floating pouch netting, vertical nets (Vertinet), horizontal nets (Horinet), pound nets (basket nets), long nets, wall nets, box nets, and hanging net rafts (Kasim et al. 2019, 2020, 2022). In general, all these variants were cultivation tools devised to protect seaweed from various pest attacks and reduce the incidence of ice-ice syndrome (Budiyanto et al. 2019; Darma et al. 2021). The principle of the tools is to cultivate seaweed in nets with various designs so that the seaweed is protected from pests of herbivorous fish and turtles. Although they have relatively the same primary function, each of these tools has advantages (Kasim et al. 2020). In this paper, we discuss the results of such research in terms of the development and economic prospects of the floating confinement method, which is one of the tools used to protect seaweed from grazing pests, epiphyte attachment, and seaborne contaminants.

22.2 Materials and Methods

22.2.1 Study Sites and Experimental Tools

Research was conducted at one of the locations for seaweed cultivation in coastal Lekeba, Southeast Sulawesi Province, Indonesia (Fig. 22.1). This location is a seaweed cultivation area that uses horizontal and vertical net tools.

The equipment used in this research was a horizontal net (Horinet) and a vertical net (Vertinet). Measurement of the total growth rate and daily growth rate was carried out by

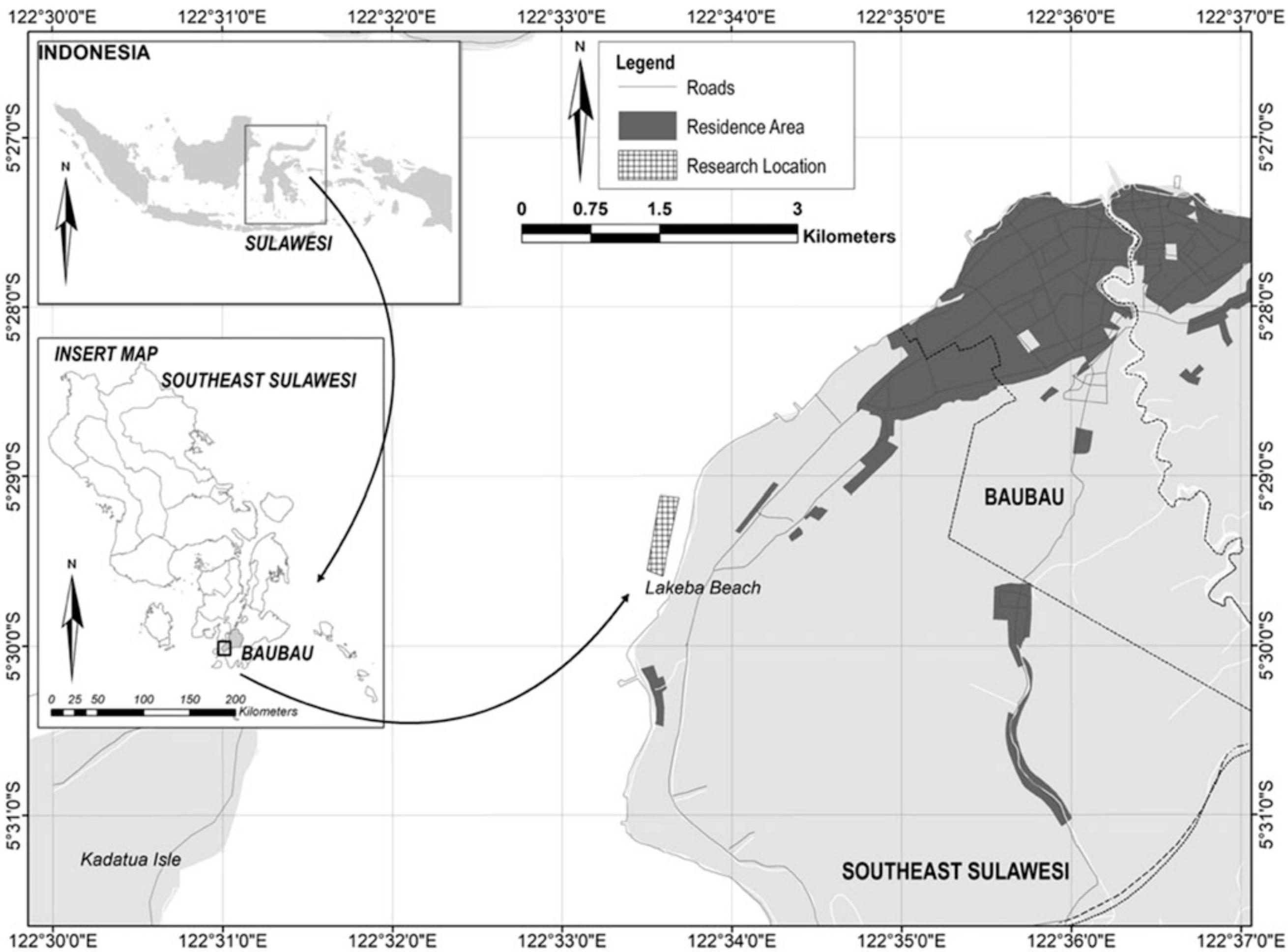


Fig. 22.1 The location of the study site in the seaweed cultivation area of Lakeba Beach, Southeast Sulawesi Province, Indonesia

measuring the weight of the *K. alvarezii* thalli every 7 days. During a 45-day cultivation period, measurements were carried out using a Horinet and a Vertinet. The Horinet was a rectangular box net composed of PVC piping used for framing that supported protective netting. The walls and floor of the box were sheathed with netting (mesh diameter 1–2 cm). The Horinet was 200 × 80 × 60 cm (Fig. 22.2).

The Vertinet is a tool comprising an equilateral rectangular bag that extends towards the bottom of the water from the water's surface. This tool consisted of two main components, namely, upper and lower pipe frames and protective netting. The PVC pipe frame is assembled separately. The primary frame size was 40 × 40 cm, and there was a protective net on the outside with a mesh size of 1 cm in diameter (Fig. 22.3).

22.2.2 Growth Rate Measurement

Growth measurements were carried out by weighing the seaweed thallus spread in horizontal and vertical nets. Weighing was performed every 7 days with five observations over 45 days. This was because *K. alvarezii* has a typical cultivation cycle of 40–45 days. The cultivation process was carried out by growing seaweed within the confinement systems, marking each thallus to facilitate the weighing process. The seaweed was continuously immersed in seawater

Fig. 22.2 A horizontal net (Horinet) was used for seaweed cultivation

Fig. 22.3 A vertical net (Vertinet) was used for seaweed cultivation

during the weighing process to avoid drying out and stressing the seaweed. Determination of the absolute growth of the seaweed was calculated using the following formula (Effendi 1997):

$$\Delta W = Wt - Wo$$

Description:

ΔW = absolute growth (g)
Wt = average weight of seaweed at the end of the study (g)
Wo = average weight of seaweed at the beginning of the study (g)

Determination of the specific growth rate (SGR) used the following formula (Luhan and Sollesta 2010):

$$SGR = \left(\frac{LnWt/LnWo}{t}\right) \times 100\%$$

Description:

SGR = specific growth rate (% in wet weight per day)
Wt = weight after t days (g)
Wo = initial weight (g)
t = time (days)

The carrageenan content was determined to assess the quality of the *K. alvarezii* thallus for each cultivation method. Carrageenan content was also measured for all *K. alvarezii* thalli inside the Horinet, Vertinet, and longline. The age of the analysed thalli was 30 days in cultivation time. Analysis of carrageenan content was carried out using the carrageenan extraction method (Rizal et al. 2016).

22.2.3 Economic Feasibility Analysis

Primary field data collection was carried out by surveying seaweed farmers. Data collection was carried out according to two methods. The first approach was to collect data by interviewing several farmers who use floating cages. Second, in-depth interviews using the snowball sampling approach were conducted with several potential farmers. Data collection was essential to explore the value of technical and economic information in the development and use of the confinement system and to analyse its economic feasibility. The data collected include information on business capital and components in investment and production obtained in one harvest. Analyses undertaken during the assessment of the economic prospects of the confinement systems are described below.

Simple business unit analysis can be performed using the formulas for total cost (TC), total revenue (TR), and profit (π) (Sugiarto 2005):

$$TC = TFC + TVC$$

Description:

TC = *total cost* (Rp)
TFC = *total fixed cost* (Rp)
TVC = *total variable cost* (Rp)

Determination of total revenue (TR) was calculated by the formula:

$$TR = P \times Q$$

Description:

TR = total revenue (Rp)
P = price (Rp)
Q = amount (Quantity) (Rp)

Analysis of the revenue/cost ratio (R/C ratio) was carried out to determine the relative profit of a business in one year against the costs used in activities. The formulation of the revenue cost ratio (R/C ratio) is as follows (Effendi and Oktariza 2006):

$$R/C = \frac{\mathrm{TR}}{\mathrm{TFC} + \mathrm{TVC}}$$

Description:

TR = total revenue (Rp)
TFC = total fixed cost (Rp)
TVC = total variable cost (Rp)

Decision-making:

If the R/C ratio is >1, the business is said to be feasible and profitable.
If the value of the R/C ratio is <1, the business is said to be unfeasible and unprofitable. If the value of the R/C ratio = 1, the business is at break-even (no profit and no loss).

To calculate the break-even point in units, use the formula:

Break-even point (units) = fixed costs/(sales price per unit – variable costs per unit)
Break-even point (sales) = fixed costs contribution margin.

Net present value (NPV) analysis is performed to assess cash flows and determine whether the project is feasible. The formula for NPV is:

$$\mathrm{NPV} = \sum_{t=1}^{n} \frac{\mathrm{CF}t}{(1+i)t} - \mathrm{Co}$$

Description:

CFt = cash flow per year in period t
Co = initial investment in year 0 (Rp)
i = discount rate (%)
t = year
n = number of years

Decision-making:

If the NPV is positive, then the investment is accepted. If the NPV is negative, then the investment is rejected.

The internal rate of return (IRR) is the interest rate that will make the total present value of the product equal to the total current value of capital expenditures.

$$\mathrm{IRR} = i1 + \frac{\mathrm{NPV1}}{(\mathrm{NPV1} - \mathrm{NPV2})}(i2 - i1)$$

Description:

$i1$ = interest rate that produces a positive NPV
$i2$ = interest rate that produces negative NPV
NPV1 = positive NPV
NPV2 = negative NPV

Decision-making:

If the IRR is greater than the loan interest, it is accepted/deserved. If the IRR is less than the loan interest, it is rejected/not feasible.

The payback period refers to the amount of time it takes to recover the cost of an investment or how long it takes for an investor to hit break-even.

$$\text{payback period} = \text{initial investment}/\text{cash flow per year}$$

22.3 Results

22.3.1 Seaweed Growth in the Horinet and Vertinet

The SGR is the rate of increase in the initial weight of *K. alvarezii* seaweed over 45 days. Measured by an initial seedling weight of 20 g, each treatment used the Horinet and Vertinet with 20 replications for each treatment. The highest and lowest SPGs are shown in Fig. 22.4.

Seaweed growth based on depth showed that depths above 100 cm were better than depths below 100 cm (Fig. 22.5).

The results of the absolute growth analysis (gr) using the Horinet and Vertinet methods were better than those using the longline method (Fig. 22.6).

From the study results, the initial weight of 20 g at the beginning of the day of breeding, after 45 days, changed to 123, 80, and 54 g using a Horinet, Vertinet, and longline, respectively. The carrageenan content of *K. alvarezii* cultivated with Vertinet, Horinet, and longline did not differ significantly (Fig. 22.7).

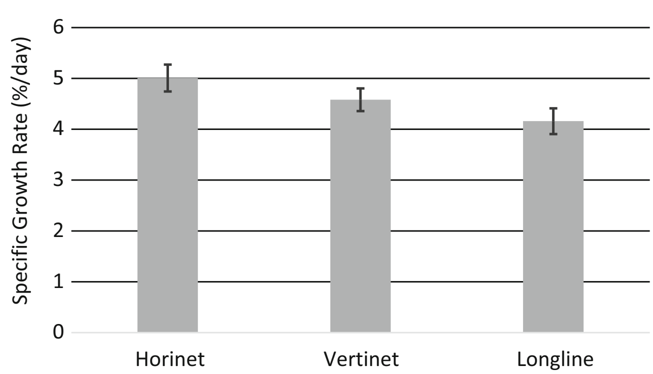


Fig. 22.4 Specific growth rate (%/day) using a Horinet, Vertinet, and longline

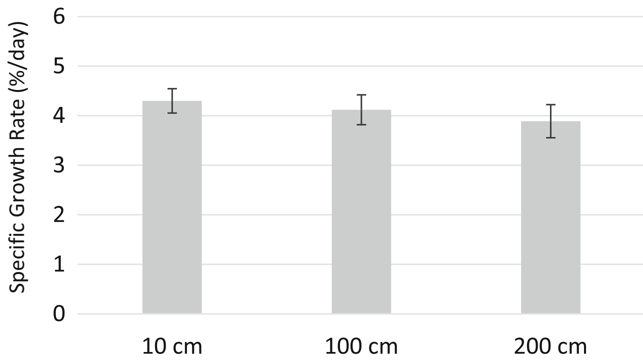


Fig. 22.5 Specific growth rate (%/day) of seaweed in a Vertinet at different depths

22.3.2 Feasibility of the Horinet and Vertinet from a Business Perspective

To determine the business viability of Horinet and Vertinet, we used some simple tests to analyse the R/C ratio. The R/C ratio is a measure of efficiency that compares a company's expenses to its earnings. It considers the cost of revenue and the total revenue. The cost of revenue includes all the expenses of manufacturing, including marketing costs. The total revenue counts the total earnings from sales during a financial period. The IRR is a metric used in financial analysis to estimate the profitability of potential investments. IRR is a discount rate that makes the NPV of all cash flows equal to zero in a discounted cash flow analysis. NPV is one of the methods used to calculate the difference between the present value of an investment and the present value of revenues. If the future net cash receipts are more significant than the present value of the investment, then the business is said to be profitable (Irmayani and Muhammad 2014; Saik 2016). The last is the payback period (PP), which refers to the amount of time it takes to recover the cost of an investment or how long it takes for an investor to reach a break-even point. Account and fund managers use the payback period to determine whether to go through with an investment. Using the previously described formula, we obtained the R/C ratio, IRR, and PP values, as shown in Table 22.1.

22.4 Discussion

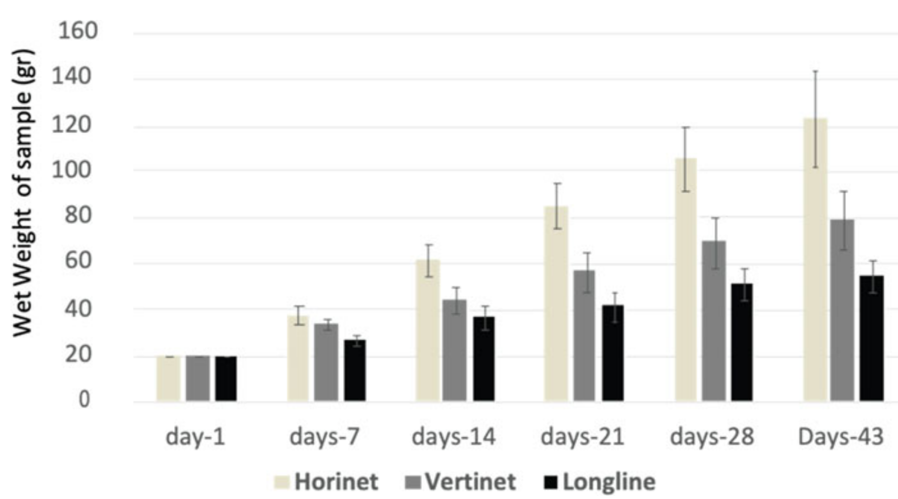
A Horinet method is a cultivation tool that utilizes sea level as a living medium for seaweed. *K. alvarezii* cultured with the Horinet were wrapped in polyethylene bags so that predators, such as barongan fish and turtles, could not graze on the seaweed. Julizar et al. (2018) explains that the use of an appropriate maintenance system, such as the floating cage, can result in an increase in seaweed production. Syarqawinagan (2017) also stated that seaweed bags are containers or places that facilitate seaweed cultivation through methods that have been developed.

The Vertinet method utilized the marine water column as a living medium for seaweed with a depth range of 50–300 cm. In a Vertinet, the seaweed is wrapped in a polyethylene bag that is a barrier to predators and prevents mud particles from directly hitting the seaweed. This method can also stimulate seaweed seedlings to increase growth (Julizar et al. 2018). Planting using the floating raft method is more effective than using the longline method because, in general, the floating raft method reduces water movement, and the intensity of light is sufficient for seaweed growth (Wijayanto et al. 2011).

22.4.1 Technical Potential of Horinet and Vertinet Development

During the cultivation process, the SGR of *K. alvarezii* cultivated using the Horinet, Vertinet, and longline methods progressed well, with average values of 5.0, 4.6, and 4.2%/

Fig. 22.6 Absolute growth (gr) during the study



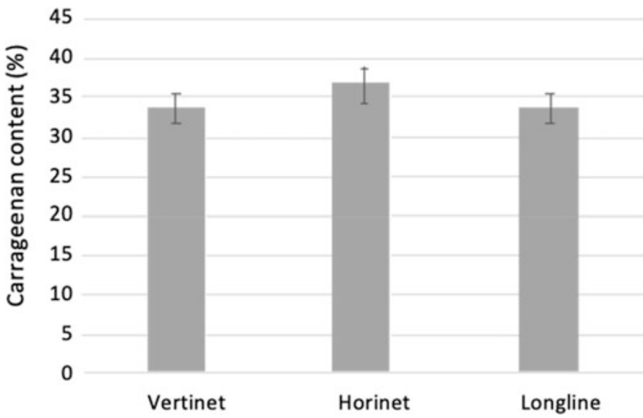


Fig. 22.7 Seaweed carrageenan content in the Vertinet, Horinet, and longline

Table 22.1 Financial feasibility of seaweed cultivation using the Vertinet and Horinet at an estimated 1 Ha/year

No	Results of calculation of the economic viability of seaweed	Vertinet	Horinet
1	R/C Ratio	4.7	1.3
3	IRR	45%	25%
4	PP (Years)	3.5	3.9

day, respectively. Both protection methods had the highest SGR compared to the longline. Bolqiah et al. (2019) reported that the SGR of *K. alvarezii* was 1.34% and 1.57% in the coastal waters of Lakorua, Southeast Sulawesi, Indonesia. Other reports of *K. alvarezii* growth rates include 1.14%/day in the Philippines (Hurtado et al. 2008), 2.0–8.1%/day in Yucatán, Mexico (Munoz et al. 2004), and 2.33–5.22%/day in the Vellar Estuary, India (Thirumaran and Anatharaman 2009). According to Nursyahran and Reskiati (2013), the first week is the phase of the start of vegetative growth. In this condition, the plant undergoes the development of mature tissue cells, so that the weight continues to increase. Mutalib and Rahman (2018) explained that the decrease in SGR was due to the low growth rate, decreased thallus weight, and the increasing age of seaweed maintenance. The cause of the decrease in SGR can be related to competition in obtaining nutrients and absorption of sunlight in the photosynthesis process. Gultom et al. (2019) stated that the denser the seaweed cultivated on one rope, the lower the growth. Amin et al. (2005) suggested that the decrease in SGR is due to the saturation of cell division. Seaweed that has undergone an adaptation process then undergoes a cell growth phase that causes slow growth. According to Gultom et al. (2019), the greater the growth weight of seaweed, the more concentrated the plant density will be. This is because the growth of new shoots and enlarged branches causes the space to become narrower, resulting in competition between plants for nutrients and sunlight.

SGR was influenced by changes in the weight and growth of the seaweed thallus. The present study showed differences in the increase in the wet weight of seaweed in the three different methods during the study. Abdan and Ruslaini (2013) stated that one of the factors affecting growth is the number of thalli. From an economic standpoint, Poncomulyo et al. (2006) noted that an SGR of 3%/day is considered quite profitable; similarly, according to Safia et al. (2019), the SGR of seaweed, considered quite profitable, is 3% weight gain per day or 21% per week. Syahlun et al. (2013) reported that a seaweed cultivation operation is categorized as good if the SGR is approximately 2%.

Absolute growth results from the final weight minus the initial weight of seaweed. The absolute growth of the mean values seen in this study on Horinet, Vertinet, and longline at initial weights of 20 gm changed to 123, 79, and 54 gm, respectively. This difference can be seen from the total weight in one harvest at 45 days. Yusup et al. (2017) explained that the growth of *K. alvarezii* in the coastal waters of Tanjung Tiram grew by 28.4 gm from the initial weight of a 5 g thallus. Faisal et al. (2012) found growth of *K. alvarezii* in the range of 41.48–49.63 gm. The use of the confinement method provided good growth conditions. The biomass in the present study had an initial weight of 20 gm. Small initial seedlings tended to grow fastest because *K. alvarezii* can obtain nutrients evenly. According to Tiwa et al. (2013), the SGR of seaweed is strongly influenced by the weight of the initial seaweed seeds to be cultivated. In the beginning, the seed weight was small, giving faster growth results because there was no competition between the thalli in obtaining nutrients. Indriani and Sumiarsi (2003) stated that nutrient fulfillment greatly affects growth. Sufficient space for seaweed causes an increase in the growth rate because the supply of nutrients takes place optimally. Small cuttings have a faster regeneration process than those with large weights.

The absolute growth graph shows that the thalli of *K. alvarezii* increased every week. This was due to the Horinet and Vertinet support system. The Horinet method had a rigid shape and seemed to protect the seaweed from pests, human activities, and the physical movement of waves. The natural condition of the seaweed attached to the substrate allows the seaweed to be squeezed between the nets and continue to grow well. In some cases, strong currents can break the seaweed thallus. However, with Horinet and Vertinet, the broken thallus will remain in the cage and will not affect the total daily weight change. In contrast, it does not provide protection from pests and only binds one side of the seaweed thallus. Continuous physical friction due to currents and waves can cause the seaweed thallus to break. The broken thallus will be washed away by the current, reducing the overall weight of the seaweed thalli.

Confined seaweeds receive good protection from attacks by herbivorous fish and turtles that choose to graze on the younger seaweed thalli (Kasim et al. 2017; Kasim and Asnani 2012). Cultivation using the floating raft method is more effective than the longline method because, in general, *K. alvarezii* is more able to obtain adequate light intensity and is less influenced by water movement caused by strong currents (Wijayanto et al. 2011). Usually, in the oceans, currents will carry solid objects, including garbage that will stick to the thallus and interfere with the photosynthesis process (Parenrengi et al. 2011). A decrease in photosynthetic activity can reduce daily activities and impact seaweed's ability to obtain nutrients (Sardianti and Widiastuti 2010). The highest absolute growth of *K. alvarezii* seaweed was obtained using the Horinet method, followed by the Vertinet and longline methods. The difference in absolute average growth in each method was because planting using the Horinet and Vertinet methods was more effective than using the longline method. The light that enters the bottom of the water is also a good determining factor for seaweed. Growth at three depths with a Vertinet (10, 100, 200 cm) did not significantly differ. The light can enter at a depth of up to 200 cm, which allows the seaweed to grow well. Space in the sea is also suitable for seaweed growth if there is good light. Faisal et al. (2012) found the growth of seaweed *K. alvarezii* at a higher surface of 41.48–49.63 gm. In the value of the weight change, it was also seen that the seaweed experienced a significant change in the surface waters at a depth of approximately 20 cm. Reported weight change values include 4.45–7.30 gm (Hamid 2009), 6.16–10.68 gm (Masyahoro and Mappiratu 2010), and 6.33–16.67 gm (Ladunta 2015). Good seaweed growth occurs because seaweed optimally utilizes sunlight for photosynthesis and nutrients. The lower light penetration ability can cause the low growth rate of seaweed with increasing sea level depth (Aditya et al. 2001; Wati 2019). This study reported that the slightly lower value at a depth of up to 200 cm on the Vertinet is the result of an uneven lighting process. The growth of *K. alvarezii* was maximal in Horinet. The growing space provided by Horinet for *K alvarezii* is better than that provided by Vertinet. Widyorini (2010) stated that light provides energy for photosynthesis, so the ability of light to penetrate at a certain depth will determine the existence of aquatic organisms. Sardianti and Widiastuti (2010) also stated that increased photosynthesis could increase the ability of marine algae to obtain nutrients. Merisca (2013) added that seaweed achieves good growth when it receives sufficient light and nutrients from its environment. When the amount of nutrients in the environment is low or limited, seaweed will absorb little, causing its growth to be low or stunted. Liang et al. (2013) reported that the depth of *Sargassum* sp. in the water, which is closely related to light transmission, must be adjusted to support a faster growth rate. The causative factors are light intensity, water temperature, and salinity, which significantly affect the rate of photosynthesis in seaweed. Vairappan et al. (2007) also stated that an important factor influencing the growth rate of seaweed is the difference in light received by the seaweed at different depths. This condition will affect the expansion of the new cell wall, which does not change appreciably when the light is limiting.

22.4.2 Economic Feasibility of Horinet and Vertinet Use

The economic feasibility of seaweed cultivation depends on many factors. One significant factor is the price that farmers get to sell their harvest. The right price will provide more profit for seaweed farmers. Farmers expect a good price for *K. alvarezii*. In the last 10 years in Indonesia, the selling price of seaweed has fluctuated greatly. The selling price range is under $1USD/kg dry. This price depends on local conditions and the needs of seaweed farmers (Langford et al. 2022).

By setting the appropriate price, this study tries to determine the feasibility of the business carried out by seaweed farmers in Southeast Sulawesi, Indonesia, especially by using Horinet and Vertinet. Horinet and Vertinet had R/C ratio values of 1.3 and 4.7, respectively. Based on these values, their business applications were judged to be feasible because the R/C value was more than one. Other research at Lakeba Beach, Baubau City, Southeast Sulawesi, reported R/C ratios of 2.9 (Sumarni 2015), 1.28 (Nursima and Nurdinana 2021), and 4.73 (Suryadin 2021) for longline, Horinet, and Vertinet, respectively, demonstrating feasibility. It is not surprising that research conducted in the same location using different methods resulted in different R/C ratio values.

The internal rate of return (IRR) value of Horinet at Lakeba Beach is 25%, with an interest rate of 12.5%. This business can be feasible because it is based on the stipulation that if the IRR is greater than the loan interest, then the business is feasible to develop (Nursima and Nurdinana 2021). Agrand (2019) explained the feasibility of cultivating *E. cottonii* using the long line method in Poso Pesisir waters, Poso Regency, Central Sulawesi Province, Indonesia. The IRR value was 50% and had an interest rate of 10%, illustrating the profitability of the business. The PP value of *K. alvarezii* cultivation using the horizontal net method was 3.9. The business was said to be feasible because the PP was smaller than the investment age of the business, which was 5 years. Agrand (2019) had a PP of 2.9 and a business investment life of 3 years. Irmayani and Muhammad (2014) studied a seaweed operation in Mallasoro Village, Bangkala District, Jeneponto Regency and reported that the IRR value obtained (47.67%) was greater than the bank interest rate used (40%). This indicated that this business could be feasible because it was based on the stipulation that if the IRR was greater than the loan interest, then the business was profitable. Similar research results by Kasim et al. (2021)

concluded that small-scale cultivators mostly used horizontal systems. This method had better efficiency and effectiveness compared to similar businesses. The horizontal net method had good economic opportunities. The efficiency value obtained was an average of approximately 3.207 with an effectiveness value of 0.00032 kg per USD. The income of farmers on Lakeba Beach was 3037 USD per year. The use of horizontal net cultivation methods provided good production values and profits for farmers.

Cultivation of *K. alvarezii* is a small business for coastal communities that is economically profitable. The small capital used will be able to provide benefits for the lives of farmers. In countries that cultivate *K. alvarezii*, such as Indonesia, the Philippines, Tanzania, India, Mexico, and the Solomon Islands, seaweed cultivation is a profitable business because the business is engaged on a small scale involving a labor-intensive production system (Cai et al. 2013; Valderrama et al. 2015). The use of this method is one of the efforts developed by seaweed farmers to increase the harvest value and the selling value of the harvested seaweed. The development of this economic value will significantly affect the lives of seaweed farmers. The longline business has been around for more than 20 years and continues to grow. As an alternative, confinement methods such as Horinet and Vertinet to increase crop production are feasible approaches. In general, the cultivation of *K. alvarezii* is profitable. The FAO conducted research and obtained test results regarding the social and economic dimensions of *K. alvarezii* cultivation (Msuya 2013; Robledo et al. 2013). In the cultivation of *K. alvarezii*, there is a large difference in the economic performance of production (Valderrama et al. 2015). This business is very dependent on the size of the area owned by the farmer. Variations in land size significantly affect crop yields and labor (Hurtado and Agbayani 2002). Research on the economic feasibility of seaweeds in the North Sea found that offshore seaweed production was not economically viable. Sensitivity analysis shows that farmers' income in one harvest must increase by approximately 300% to be profitable (van den Burg et al. 2016). In contrast, the cultivation of *K. alvarezii*, if managed properly, can be profitable. Seaweed farmers are motivated to perform aquaculture business with the hope of good and better profits than other fishery businesses. A farmer will benefit from increasing his skills and ability to manage his cultivated area to obtain funds for his daily activities (Mariño et al. 2019; Steenbergen et al. 2017).

22.5 Conclusion

The development of protective cultivation using special tools such as Horinet and Vertinet can result in increases in absolute growth and specific growth of *K. alvarezii* that are greater than those observed on longlines. The new Horinet and Vertinet innovations were first introduced and developed by seaweed farmers in several areas, especially in Indonesia. These two innovations effectively protected the seaweed from fish and turtle pests. The best indicator of their success is the high rate of daily growth, reaching 6%/day. The economic aspect was one of the analytical tools to provide recommendations for feasibility. The Horinet and Vertinet methods have a business feasibility value that deserves to be developed. The analysis showed that a return on investment can occur in three years or less. The profit value is very good, so this tool is feasible as an innovation for the future cultivation of *K. alvarezii* in Indonesia.

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