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Cultivation Methods Using Kajarula Technology to Increase the Productivity of Seaweed (Kappaphycus alvarezii)

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ABSTRACT

Seaweed (*Kappaphycus alvarezii*) is a potential marine biological resource in Indonesia, especially in Palasa Village, Sumenep, East Java. The conventional (long-line) method applied in cultivation is still not effective and efficient enough. Therefore, there is a need to develop cultivation methods to increase seaweed productivity. This study aims to analyze seaweed productivity using *Kajarula* (Seaweed Net Bag) technology at the cultivation location of Palasa Village, Sumenep, East Java. This study uses the Group Random Design (RAK) method. The research began with the measurement of the physical-chemical quality of the waters, the creation of a design for making *Kajarula* from the clumps, monitoring the growth of seaweed, monitoring the quality of waters, monitoring pests and diseases, and the productivity of seaweed. Data were analyzed using seaweed productivity parameters including biomass production, relative growth, growth, absolute growth rate, and total harvest. The data obtained were then tabulated using the MS Excel application to produce representative data in the form of graphs and tables, and analyzed descriptively. From the results of the study, seaweed cultivated for 42 days produced an average biomass production of 5.54 ± 0.27 kg/unit, a relative growth of 153.41 ± 10.97%, a growth of 754 ± 27 g/binding point, an absolute growth rate of 239.32 ± 21.95 g/day, and a total harvest of 5.26 – 5.82 kg per unit bag. The water quality conditions in these waters are in the optimal range for supporting the growth of seaweed. The productivity of seaweed cultivation using *Kajarula* technology shows optimal growth and yield.

Keywords:

Cultivation, Kajarula, Kappaphycus alvarezii, Productivity, Environmentally Friendly.

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INTRODUCTION

Kappaphycus alvarezii is a seaweed with a high carrageenan content that can be used as a source of raw materials for the food industry, namely thickeners, gel-forms, and food stabilizers (Adharini et al., 2019; Aris et al., 2021; Bhuyar et al., 2021; Kasim & Mustafa, 2017; Lantah et al., 2017; Yulianti et al., 2021). Therefore, in Indonesian waters, *K. alvarezii* is one of the preferred seaweeds that is widely cultivated. However, the production of *K. alvarezii* in Indonesian waters is still fluctuating; this occurs due to seasonal changes, susceptibility to diseases, pests, and infections, resulting in a decrease in carrageenan quality and even causing crop failure (Mulyono et al., 2022; Simatupang et al., 2021; Tirtawijaya et al., 2018; Zakaria et al., 2019). In Madura, Sumenep Regency, especially in Palasa Village, the waters are widely used as a *K. alvarezii* cultivation area. The type of *K. alvarezii* cultivated in the village is the green variety of *K. alvarezii*. The cultivation of *K. alvarezii* at this location is one of the sources of income for the local community, but the productivity of seaweed in Palasa Village is relatively low.

Technological developments have encouraged the use of seaweed to be more widespread, thus driving demand and production in various countries. Large-scale seaweed cultivation can be realized through increased production and continuity of raw materials, and this can help improve the economic welfare of rural communities (Kite-Powell et al., 2022). However, seaweed cultivation in Palasa Village, Sumenep Regency is currently not optimal because cultivators are still using conventional methods. The long-line method is a conventional method that is often applied in seaweed cultivation that allows for pest attacks and ruptures of seaweed thallus, large currents and waves that cause a decrease in production (Pratiwi et al., 2023). One of the obstacles faced by seaweed cultivators is thallus loss. Limited or conventional cultivation technology can cause seaweed productivity to be less than optimal (Abdullah et al., 2020; Montúfar-Romero et al., 2023; Satriani et al., 2023).

Several studies have attempted to address these challenges. Research by Mako (2018) demonstrated that the use of protective bags in cultivation can shield seaweed from pest disturbances. Similarly, Erbabley et al. (2020) found that net bag technology could enhance growth and protect against thallus breakage during strong currents. Kusuma et al. (2021) further supported that the net bag method, a modification of the long-line method, effectively utilizes water columns. However, despite these advancements, the application of specifically designed net bag technology like *Kajarula* remains underexplored, particularly in the context of Palasa Village's unique environmental conditions. Previous research in the area, such as that by Pratiwi (2020), has primarily focused on general water quality assessments rather than integrated technological solutions that address multiple production constraints simultaneously.

Seaweed productivity can be increased by being supported by sustainable cultivation methods that are appropriate in their application. Net bag technology is a technology that is able to increase the growth of seaweed, protecting against pest attacks and thallus breakage when strong currents occur. The net bag method is one of the modifications of the long-line method by utilizing marine water columns. This gave rise to the idea of optimizing productivity and reducing these risks by applying seaweed cultivation methods using *Kajarula* technology or seaweed net bags. This method can be a solution to the problem of declining production due to environmental disturbances, such as pest attacks, losses due to strong currents and waves, as well as the use of plastic bottle floats in conventional cultivation methods that are not environmentally friendly. This study aims to fill the research gap by specifically evaluating the effectiveness of the locally adapted *Kajarula* technology in improving the productivity of *K. alvarezii* in Palasa Village, comparing its performance directly against the conventional long-line method across multiple growth and yield parameters.

The benefits of this research are multidimensional, covering practical, environmental, scientific, and policy aspects. For farmers, *Kajarula* technology offers a practical solution to increase productivity and income while reducing the risk of crop failure. From an environmental point of view, this method is more environmentally friendly by reducing the use of plastic bottle floats. Scientifically, this study provides empirical data on the effectiveness of *Kajarula* technology for the development of sustainable cultivation methods. The research findings can also support the government in formulating policies to

empower coastal communities, as well as serve as a reference for further research on optimizing seaweed cultivation technology.

METHOD

This series of research activities started from June to December 2024, which included the preparation of *Kajarula* construction design, site preparation, and the cultivation process. Seaweed cultivation was carried out from August to September 2024. This research activity consists of several stages of production, including: preparation of 10 units of *Kajarula*, selection and binding of seaweed seedlings, monitoring of growth, water quality, pests and diseases, and harvesting. *Kajarula* technology is designed using a 1-inch PE mesh, with a construction design of 40 cm in diameter formed around a wooden frame and a height of 50 cm per unit bag. The rope construction consists of the main buoy, auxiliary buoy, main rope, riser rope, anchor, and anchor rope as seen in Figure 4.1. Buoys serve to maintain the depth of seaweed from the water surface. Furthermore, *Kajarula* was installed on the main rope. The *Kajarula* is hung on the main rope with a distance of 2 m between units, and at a depth of 50 cm from the water surface as seen in Figure 1. According to Sahabati (2016), seaweed cultivation with a depth of 50 cm from sea level shows optimal growth. The distance and depth of seaweed cultivation affect growth, light penetration ability, health, photosynthesis, and competition to obtain nutrients.

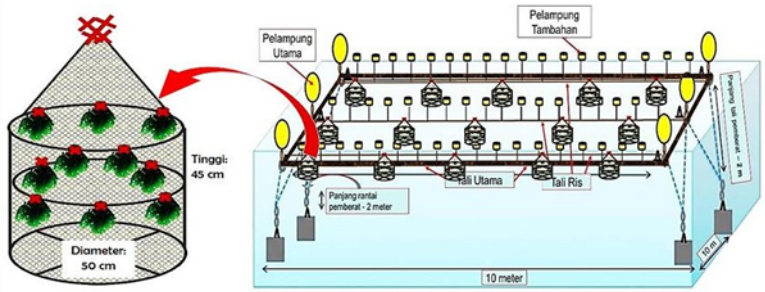


Figure 1. **KAJARULA design in the cultivation of seaweed (Kappaphycus alvarezii)**
Source: Modification from Sahabati, 2016

The seaweed cultivation location used has sandy substrate conditions mixed with a little mud, with a water area of 150 m². According to Irfan (2015), the substrate condition of the waters for seaweed cultivation is sand mixed with mud with a little coral or coral fragments. The selection of the seaweed cultivation location in Palasa Village, Sumenep, East Java for the cultivation activity is known to be quite optimal in supporting the growth of seaweed.

The water quality parameters observed in this study, including temperature, transparency, current velocity, pH, salinity, and dissolved oxygen, were measured in-situ in the field, while nitrate and phosphate parameters were analyzed in the laboratory. Water samples were collected for pH, nitrate, and phosphate observations using a 1,500 mL plastic bottle. Then, the water samples were first stored in a cool box. Furthermore, the water samples were analyzed at the Environmental Laboratory of the Environment and Forestry Service, East Nusa Tenggara Province.

Monitoring of seaweed growth was carried out by sampling for weight growth during maintenance. Seaweed sampling was carried out randomly at 1 point on each unit. Seaweed

that had been taken from the *Kajarula* unit was then weighed to determine wet weight and daily growth rate data. Furthermore, the seaweed samples were returned to be tied back into the *Kajarula* unit. Harvesting was carried out by transporting all *Kajarula* units to the mainland and calculating the total production yield.

This research is a field study that includes observations, interviews, carrying out the seaweed cultivation production process by applying *Kajarula* technology, as well as comparing partner data on conventional (long-line) cultivation activities in Palasa Village, Sumenep, East Java.

Seaweed productivity parameters include biomass production, relative growth, growth, absolute growth rate, and total harvest, referring to the methods of Arisandi (2021). The water quality parameters observed during maintenance, including temperature, transparency, current velocity, pH, salinity, dissolved oxygen, nitrates, and phosphates, refer to the methods of Pratiwi and Wiryana. Growth was observed by sampling the weight of seaweed, while the water quality parameters were measured once a day at 10:00 *WIB*. Sampling of seaweed weight and water quality was carried out on days 0, 10, 20, 30, and 42. The data obtained were then tabulated using the MS Excel application to produce representative data in the form of graphs and tables, and analyzed descriptively.

RESULTS AND DISCUSSION

The results of this study also show that the growth of seaweed at each binding point is equally fertile, where it is known that the initial weight of 200 ± 0.00 g/binding point increases to 754 ± 27 g/binding point at harvest. The final observation results showed that the application of Kajarula technology produced an average absolute growth of 239.32 ± 21.95 g/day or 554.00 ± 27.23 g/cycle (42 days of maintenance) (Figure 3). Preliminary research in our observation of seaweed cultivators in Palasa village shows that the average growth of seaweed with the long line method only reaches 140.82 ± 19.46 g/day. This proves that the Kajarula method is more effective in supporting optimal seaweed production performance.

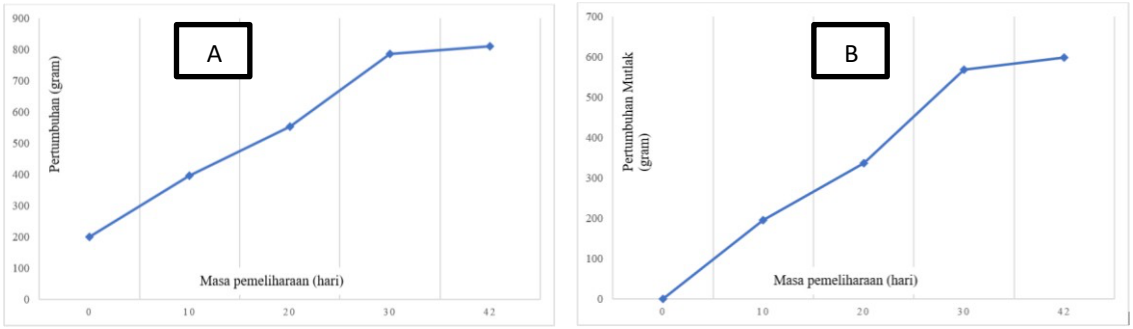


Figure 2. Growth of Kappaphycus alvarezii seaweed during the maintenance period with the application of Kajarula's technology: (A) growth rate and (B) absolute growth rate

Source: Research data, 2024

Observation data showed that the low productivity of seaweed in the long line method was caused by the attack of baronang fish pests that bite and eat part of the seaweed thallus.

The application of Kajarula technology in seaweed cultivation with a construction size of 50 cm high and a diameter of 40 cm is considered very appropriate. It is proven that the construction can protect seaweed from pest disturbances, such as Baronang fish and turtles that eat seaweed, as well as aquatic plants (mosses) which are nutritional competitors that can inhibit the growth of seaweed. This is in accordance with the opinion, giving bags to seaweed cultivation can protect against pest disturbances such as baronang fish, barnacles, and aquatic plants (mosses) that can inhibit the growth of seaweed. In addition, also in the 3rd stage of observation (between the 30th and 42nd days) there have been storms, wave blows, and strong water currents, causing some seaweed cultivated using the long line method to be damaged, the seaweed thallus broken, and even washed away by the current. Meanwhile, seaweed cultivated using Kajarula is safer and stronger, so as to avoid current attacks.

In addition to more optimal growth factors, the condition of seaweed has a brighter color compared to the long line method. This is because the cultivated seaweed is at a depth of 50 cm where the water conditions are cleaner. In contrast to the long line method which is positioned on the surface of the water, where there is a lot of garbage and contaminants floating around. In addition, seaweed cultivated using the long line method costs more money and energy in the maintenance process, such as cleaning barnacles attached to seaweed. If there are too many barnacles, the seaweed must be lifted ashore to be soaked with fresh water.

Water quality is one of the factors that plays an important role in the success of a seaweed cultivation business. According to Pratiwi, the aquatic environment of Palasa Village has low rainfall conditions, strong sunlight intensity, and some corrugated beaches are quite optimal in supporting the productivity of seaweed cultivation. According to Ateweberhan, the growth of seaweed is greatly influenced by seasonal changes, where productivity is higher in the dry season, which is between February and June. Table 1. The quality of Kappaphycus alvarezii seaweed cultivation water in the waters of Palasa Village during the 42-day maintenance period.

Table 1. **Water quality of Kappaphycus alvarezii seaweed cultivation in the waters of Palasa Village during the 42-day maintenance period**

Parameters	**Unit**	**Range Current**	**Range Optimal**	**Reference**
Temperature	0C	29 – 31,5	25,00 – 31,00	Yulius et al. (2019)
Brightness	Cm	40 – 50	20 – 50	Muslimin & Sari (2017)
Speed Current	m/s	0,30 – 0,40	0,20 – 0,40	Logo et al. (2018)
Ph		7,8 – 8,0	7,3 – 8,0	Rusdi et al. (2017)
Salinity	g/L	32 – 34	28,00 – 33,00	Umam & Arisandi (2021)
Oxygen Dissolved	mg/L	5,50 – 8,00	≥ 5	Andayani & The End (2018)
Nitrate	mg/L	0,001 – 0,025	0,001 – 0,202	Atmanisa et al. (2020)
Phosphate	mg/L	0,001	0,022 – 0,049	Logo et al. (2018)

Source: Data processed from Pratiwi, 2020; Logo et al., 2018; Rusdi et al., 2017)

Based on the results of water quality measurement data, it is known that during maintenance conditions of temperature, brightness, flow velocity, pH, salinity, dissolved oxygen, nitrates, and phosphates are still in the optimal range (Table 2.1). This shows that the water quality condition of Palasa Village is quite optimal as a location for seaweed cultivation activities and is able to support in producing optimal productivity. Optimal water quality is one of the requirements for the success of cultivation activities. This is also in line with the results of research by Garcia-Poza, seaweed cultivation is highly dependent on the quality of the surrounding aquatic environment, so that it can produce optimal productivity and harvest quality.

Pests can be predators for cultivated biota, so they can result in low crop yields. The type of pest found during the maintenance process is baronang fish. The growth of seaweed that was so fertile that it was able to grow spread out of the Kajarula unit in the 5th week of maintenance (day 40) caused the baronang fish to bite the thallus (Figure 4A). This also happens in a study, pest attacks on net bag technology only occur on the outside due to the nature of seaweed that develops by lengthening the thallus, so as to allow the thallus to come out of the net and can be eaten by fish. The bite marks are an entry point for pathogenic bacteria.



Figure 4. Pests and diseases that attack seaweed during the rearing process: (A) Baronang fish bite marks and (B) ice disease on seaweed thallus

Source: Research documentation, 2024

The identification of diseases that attack seaweed during the study is ice-ice infection (Figure 4B). This disease appears beginning with the formation of spots, spots or yellow-brown spots. After 3 days, it appears that the stem and thallus of the seaweed lose their elasticity, become white, soft, and break from the bond, then fall to the bottom of the water. Ice-ice disease infections appear at the end of the dry season with weak ocean current conditions. This also causes the sampling weight to be reduced. According to Erbabley, (2020), ice-ice disease attacks cause damage to the thallus which results in decreased growth and production and even crop failure. However, in this study, the problem is not a big obstacle that makes it very difficult or causes failure in the cultivation process, because the affected part is only a small part.

Seaweed harvesting is carried out as a whole by means that all Kajarula units are removed and transported to the mainland, then the seaweed is removed from inside Kajarula. Next, all seaweed is weighed for biomass (wet weight), then arranged in a drying place (para-

para) to be dried in the sun for 2-3 days. Direct drying during post-harvest (seaweed is still fresh) aims to reduce moisture content and microbial growth, so that it can extend storage time, maintain quality, and facilitate packaging or transportation.

Total seaweed production with the application of Kajarula technology can reach 5.54 ± 0.27 kg/unit bag. Based on the observation results, the total production of seaweed cultivation with the long line method is only around 2.14 – 3.5 kg, while using the Kajarula method is higher, which is around 5.26 – 5.82 kg/bag unit. The total harvest produced using 40 kg of seaweed seeds can produce as much as 97 kg of fresh seaweed. This is in line with the results of the study (Syarqawi, 2017), the total production of seaweed using net bags ranges from 6.11 ± 1.32 kg/unit of bags, compared to the long line method which only ranges from 0.68 ± 0.52 kg/unit due to storms so that many seaweed are broken and washed away by the current. Other studies also show that seaweed cultivation with conventional long-line methods is only able to produce an average relative growth of 140.82 ± 19.46 g/dot and a relative growth of 91.7 ± 9.73% (Serihollo, 2021). However, the results of this study prove that seaweed cultivation with the application of Kajarula technology can support optimal seaweed productivity and the average growth is higher reaching 754 ± 27 g/binding point and the growth rate is 153.41 ± 10.97 %/day.

CONCLUSION

The application of *Kajarula* technology to the productivity of *Kappaphycus alvarezii* seaweed on the coast of Palasa Village, Sumenep Regency demonstrates optimal growth and yields. Seaweed cultivated for 42 days produced an average biomass production of 5.54 ± 0.27 kg/unit, a relative growth of 153.41 ± 10.97%, an average growth of 754 ± 27 g/binding point, an absolute growth rate of 239.32 ± 21.95 g/day, and a total harvest of 5.26 – 5.82 kg per unit bag. Additionally, water quality conditions during the maintenance period were within the optimal range for supporting seaweed growth.

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