Application of kajarula technology to the productivity of seaweed *Kappaphycus striatus* at Tablolong Beach, West Kupang, East Nusa Tenggara

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**Abstract.** Seaweed *Kappaphycus striatus* is a potential marine biological resource in Indonesia, but the cultivation uses still the conventional method (long line). The decline in production yields is affected by environmental disturbances, such as pest attacks and release due to strong currents and waves, which are also not environmentally friendly. Therefore, it is necessary to develop new cultivation methods to increase seaweed productivity. This study aims to analyze the productivity of seaweed using Kajarula (*Kantong Jaring Rumput Laut*, also known as seaweed net bag) technology at Tablolong Beach, West Kupang, East Nusa Tenggara. The research design used for observation data was randomized pretest-posttest Control Group Design. Next, this research is a case study that includes interviews, observations, and following the process of production of seaweed using Kajarula technology. The production performance of seaweed cultivated for 42 days resulted in biomass production of 7.54 ± 0.27 kg/units with an average relative growth of 153.41 ± 10.97 %/day, a growth rate of 239.32 ± 21.95 g/day, and a total harvest of 5.82 – 7.45 kg/units. The water quality conditions in these waters are within the optimal range to support seaweed growth. The productivity of seaweed cultivation using Kajarula technology shows optimal growth and yields.

**1 Introduction**

Seaweed is one of Indonesia's potential marine biological resources [1] and has a sustainable production system [2]. Indonesia is one of the largest seaweed producers, with a total production of more than 23 million tons [3]. The type of *Kappaphycus* seaweed belongs to the group of algae that are economically and commercially cultivated in nearly 30 countries,

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including Indonesia [4]. The potential for seaweed cultivation in Kupang district, East Nusa Tenggara province, as a center for the development of seaweed farms with 10,086 hectares of cultivated land, can achieve a total production of 305,333 tons per year from the genus *Eucheuma* sp. and *Kappaphycus* sp. [5, 6, 7]. The number of seaweed cultivators in this area has reached 64,095 people spread across 21 regencies, one of which is in Tablolong village, West Kupang district. As a livelihood, seaweed cultivation is a typical activity by residents [8, 9, 10].

Technological developments have encouraged seaweed to become more expansive, thus driving demand and production in various countries [11]. Seaweed cultivation on a large scale can be realized through increased production and continuity of raw materials [12, 13], which can help improve the economic welfare of rural communities [14, 15]. However, seaweed cultivation in Tablolong village needs to be more optimal because farmers still use traditional methods. The long line method is a conventional method often applied in seaweed cultivation, allowing for pest attacks and the breaking of the seaweed thallus [16], currents, and large waves, causing a decrease in production [17]. One of the obstacles faced by seaweed cultivators is thallus loss. Limited cultivation technology can cause seaweed productivity not to be optimal [18].

Seaweed productivity can be increased by using sustainable cultivation-supporting methods that are effective in their application. This led to optimizing productivity and reducing these risks by implementing seaweed cultivation methods using Kajarula (*Kantong Jaring Rumput Laut*, also known as seaweed net bags) technology. The Kajarula technology is a technology that can increase seaweed growth and protect it from pest attacks and thallus that break when strong currents occur [19]. The long line method is cultivating seaweed using a rope stretched from one point to another in the seawater column (euphotic) near the water surface. The length of the rope used ranges from 25 – 50 meters and is equipped with a buoy rope and anchor. The Kajarula method modifies the long line method by utilizing seawater columns. The effectiveness of Kajarula technology is still focused on research into cultivating Sakol *Kappaphycus striatus* because it is the best seaweed strain originating from Kupang. This method can solve the problem of decreasing production yields, which are affected by environmental disturbances, such as pest attacks, release due to strong currents and waves, and the use of plastic bottle floats in conventional cultivation methods, which are not environmentally friendly. This study aims to analyze the application of Kajarula technology to the productivity of seaweed *Kappaphycus striatus* at Tablolong Beach, West Kupang, East Nusa Tenggara.

## 2 Methods

### 2.1 Research periods and locations

This series of research activities starts from June to December 2020, including preparing Kajarula construction designs, site preparation, and the cultivation process. Seaweed cultivation is carried out from August to September 2020. The research location is on Tablolong Beach, Tablolong Village, West Kupang, East Nusa Tenggara.

### 2.2 Design of experiment

This research design used for observation data was randomized pretest-posttest Control Group Design. Next, this research is a case study that includes interviews, observations, and following the process of production of seaweed using Kajarula technology, as well as comparing partner data on conventional cultivation methods (long line) at Tablolong Beach,
West Kupang, East Nusa Tenggara.

2.3 Research procedure

This research activity consisted of several stages of production, including the preparation of 20 units of Kajarula, selection and binding of seaweed seeds, growth monitoring, water quality, pests and diseases, and harvesting. Kajarula technology is designed using 1-inch PE nets, with a construction design with a diameter of 50 cm formed by an iron frame and a height of 45 cm per bag unit. The rope construction consists of main buoys, additional buoys, main ropes, rise ropes, anchors, and anchor ropes (Figure 1). The buoy maintains the seaweed's depth from the water's surface.

In the next step, install the Kajarula on the rope. The Kajarula were suspended from ropes at a distance of 2 m between units and a depth of 50 cm from the water surface (Figure 1). Seaweed cultivation with a depth of 50 cm from sea level shows optimal growth [20]. The distance and depth of seaweed cultivation affect growth, ability to penetrate light, health, photosynthesis, and competition for nutrients [21].

![Fig. 1. Design of Kajarula technology on seaweed Kappaphycus striatus at Tablolong Beach](image)

The seaweed cultivation location used has basic conditions of sandy waters mixed with a little mud with a water area of 150 m². The basic condition of the waters for seaweed cultivation is sand mixed with mud with a bit of coral or coral fragments [22]. The selection of the location of the waters on the Tablolong beach for aquaculture activities is known to be quite optimal in supporting the growth of seaweed.

The number of Kajarula used was 20 units, with 1 unit of Kajarula having 10 tie points, each tied to seaweed seeds weighing 200 g/tie point. The seaweed seeds used were 2 kg/unit or 40 kg/cycle. Kajarula’s maintenance was carried out during weekly sampling activities (Figure 2).

Sampling was carried out to calculate and monitor the weight growth of seaweed during maintenance. Seaweed sampling was carried out randomly as much as 1 point in each unit. Seaweed taken from the Kajarula's unit was weighed to determine the wet weight and daily growth rate data. Furthermore, the seaweed samples were returned to be bound into the Kajarula unit. Harvesting is done by transporting the Kajarula to the mainland and calculating the total yield (Figure 2).
Fig. 2. The process of setting up seaweed using the Kajarula technology: (A) tying the seaweed seeds into units; (B) transporting units containing seeds from land to boats; (C) the process of tying the Kajarula unit to rise ropes at sea; and (D) the Kajarula units raised to the surface during weekly sampling.

Water quality parameters observed in this study, including temperature, brightness, current speed, pH, salinity, and dissolved oxygen, were measured in situ in the field. In contrast, nitrate and phosphate parameters were analyzed in the laboratory (Table 2)—the water sampling for observing nitrate and phosphate using a 1,500 mL plastic bottle. Then, the sample water is first stored in a cool box. Furthermore, water samples were analyzed at the Environmental Laboratory of the Environment and Forestry Service, East Nusa Tenggara province.

2.4 Data analysis

Seaweed productivity parameters include production biomass, relative growth, growth, absolute growth rate, and total harvest. Water quality parameters were observed during maintenance, including temperature, brightness, current speed, pH, salinity, dissolved oxygen, nitrate, and phosphate. Growth was observed by sampling the weight of the seaweed, while the water quality parameters were measured daily at 10:00 a.m. Weight sampling and water quality were carried out on days of culture 0, 10, 20, 30, and 42. The sampling data obtained was tabulated and analyzed descriptively using Ms. Excel, producing representative data in graphs and tables.

3 Result and discussion

3.1 Seaweed production performance

Growth is an increase in length, weight, or volume in a specific time [23]. Seaweed cultivation using Kajarula technology shows an increase in relative growth, which correlates with increased seaweed production (Figure 3). The initial weight of the cultivated seaweed seedlings was 2 ± 0.00 kg/unit. They could produce 7.54 ± 0.27 kg/unit biomass production at harvest time (Figure 3A). In addition, the average relative growth of seaweed reached 153.41 ± 10.97 %/day (Figure 3B). However, the highest relative growth in seaweed cultivated using the long line method for 35 days of culture can reach 58.17 %/day [24]. This proves that seaweed cultivation with the application of Kajarula can produce relative growth and higher production levels than conventional long-line methods.

The results of this study also showed that the growth of seaweed at each tie point was equally fertile, where it was known that the initial weight of 200 ± 0.00 g/tie points increased to 664 ± 27 g/tie points the tie at harvest. The final observation showed that applying Kajarula
technology resulted in a growth rate of 239.32 ± 21.95 g/day (Figure 3). Preliminary research in our observation of seaweed cultivators in Tablolong village found that the average relative growth of seaweed using the long line method only reached 140.82 ± 19.46 g/day (Table 1). This proves that the Kajarula method supports optimal seaweed production performance more effectively.

![Graphs showing biomass production, relative growth, growth rate, and absolute growth rate over the days of culture.](image)

**Fig. 3.** Productivity of seaweed *Kappaphycus striatus* during maintenance (42 days of culture) with the application of Kajarula technology: (A) biomass production, (B) relative growth, (C) growth rate, and (D) absolute growth rate

<table>
<thead>
<tr>
<th>Day of Culture</th>
<th>Biomass Production (kg)</th>
<th>Longline</th>
<th>Kajarula Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>10</td>
<td>2.14</td>
<td>5.82</td>
<td>6.40</td>
</tr>
<tr>
<td>20</td>
<td>3.00</td>
<td>6.40</td>
<td>7.45</td>
</tr>
<tr>
<td>30</td>
<td>3.40</td>
<td>6.80</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>3.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative Growth</td>
<td>140.82 ± 19.46 g/day</td>
<td>239.32 ± 21.95 g/day</td>
<td></td>
</tr>
<tr>
<td>Biomass Production</td>
<td>2.14 – 3.5 kg</td>
<td>5.82 – 7.45 kg</td>
<td></td>
</tr>
</tbody>
</table>

Observational data showed that the productivity of seaweed is low in the long line method due to attacks by Baronang fish, which bite and eat the thallus of the seaweed, and also due to wave currents causing falls and loss of seaweed (Table 1, Figure 4A). Applying Kajarula technology to seaweed cultivation with a construction measuring 45 cm high and 50 cm in diameter is appropriate. It is proven that this construction can protect seaweed from pests, such as rabbitfish and turtles that eat seaweed, as well as aquatic plants (moss), which are competitors for nutrients that can inhibit seaweed growth. Providing bags for seaweed cultivation can protect against pests such as Baronang fish, barnacles, and aquatic plants (moss), which can inhibit seaweed growth [25]. In addition, during the 3rd stage of
observation (between the 30th and 42nd day), there were storms, waves, and strong water currents, causing some of the seaweed cultivated using the long line method to suffer damage, the broken grass thallus and even drifting away with the currents. Seaweed cultivated using Kajarula is safer and stronger, avoiding current attacks.

In addition to a more optimal growth factor, the condition of the 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 located on the water's surface, where there is a lot of floating trash and contaminants. In addition, seaweed that is cultivated using the long line method incurs more costs and labor in the maintenance process, such as cleaning the barnacles attached to the seaweed. If too many barnacles exist, the seaweed must be brought ashore soaked in fresh water.

3.2 The water quality

Water quality is a factor that plays an important role in the success of a seaweed cultivation business. The aquatic environment of the East Nusa Tenggara region has conditions of low rainfall, strong sunlight intensity, and some rocky beaches that are rocky, which are quite optimal in supporting the productivity of seaweed cultivation [26]. Seasonal changes strongly influence seaweed growth, where productivity is higher in the dry season, from April to August [27].

Water quality monitoring data shows that temperature conditions, brightness, current speed, pH, salinity, dissolved oxygen, nitrate, and phosphate remain within the optimal range during maintenance (Table 2). This shows that the water quality conditions at Tablolong Beach are optimal for seaweed cultivation activities and can support optimal productivity. Optimal water quality is a prerequisite for the success of aquaculture activities [32, 33, 34]. Seaweed cultivation directly depends on the quality of the surrounding aquatic environment to produce optimal productivity and crop quality [35].

Table 2. Water quality of seaweed *Kappaphycus striatus* at Tablolong Beach during maintenance

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Actual Ranges</th>
<th>Optimal Ranges</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>ºC</td>
<td>28.00 – 31.15</td>
<td>25.00 – 31.00</td>
<td>[28]</td>
</tr>
<tr>
<td>Brightness</td>
<td>cm</td>
<td>40.00 – 50.00</td>
<td>20.00 – 50.00</td>
<td>[18]</td>
</tr>
<tr>
<td>Current speed</td>
<td>m/s</td>
<td>0.30 – 0.40</td>
<td>0.20 – 0.40</td>
<td>[29]</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>7.80 – 8.10</td>
<td>7.30 – 8.00</td>
<td>[30]</td>
</tr>
<tr>
<td>Salinity</td>
<td>g/L</td>
<td>33.75 – 34.75</td>
<td>28.00 – 33.00</td>
<td>[24]</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>mg/L</td>
<td>5.50 – 8.00</td>
<td>≥ 5.00</td>
<td>[12]</td>
</tr>
<tr>
<td>Nitrate</td>
<td>mg/L</td>
<td>0.001 – 0.025</td>
<td>0.001 – 0.202</td>
<td>[31]</td>
</tr>
<tr>
<td>Phosphate</td>
<td>mg/L</td>
<td>0.001</td>
<td>0.022 – 0.049</td>
<td>[29]</td>
</tr>
</tbody>
</table>

3.3 Pest and disease monitoring

Pests can become predators for cultivated biota, resulting in low yields [36, 37]. The types of pests found during the rearing process were Baronang fish. The growth of seaweed, which was so fertile that it spread out from the Kajarula unit on the 5th week of rearing (40th day), caused the rabbit fish to bite the thallus (Figure 4A). Pest attacks in the cultivation method using Kajarula only occur outside the unit. It was caused by the nature of seaweed growing by elongating the thallus, allowing it to grow and bloom until it comes out between the meshes so that fish can eat it. The bite marks become an entry point for pathogenic bacteria.
Identification of the disease that attacked seaweed during the study was ice-ice infection (Figure 4B). This disease appears beginning with the formation of yellow-brown spots or spots. After three days, it was seen that the stem and thallus of the seaweed lost their elasticity, became white soft, broke off from the bonds, and then fell to the bottom of the waters. Ice-ice disease infection with weak ocean currents appears at the end of the dry season. This also causes the sampling weight to decrease. Ice-ice disease attacks cause damage to the thallus, which results in decreased growth and production and even crop failure. However, in this study, these problems were not major obstacles that complicated greatly or caused failure in the cultivation process because only a tiny portion was affected.

3.4 Seaweeds harvest

Seaweed harvesting is carried out as a whole using all Kajarula units being released and transported to the mainland. Then, the seaweed is removed from inside the Kajarula. Next, all the seaweed is weighed for its biomass (wet weight), then arranged in a drying rack (para-para) to be dried in the sun for 2 – 3 days. Direct drying during post-harvest (fresh seaweed conditions) aims to reduce water content and microbial growth, extend storage time, maintain quality, and facilitate packaging or transportation [38].

Based on observations, the total production of seaweed cultivation using the long line method was only around 2.14 – 3.5 kg, while using the Kajarula method was higher, around 5.82 – 7.45 kg/unit bags (Table 1). The total harvest using 40 kg of seaweed seeds can produce as much as 132 kg of fresh seaweed. This is in line with the results of other studies. Total seaweed production using net bags ranged from 6.11 ± 1.32 kg/units, compared to the long line method, which only ranged from 0.68 ± 0.52 kg/line units due to storms so many seaweeds were broken and drifted away [39], and average relative growth of 140.82 ± 19.46 g/tie points and relative growth of 91.7 ± 9.73 %/day [17]. However, the results of this study prove that seaweed cultivation with the application of Kajarula technology can support optimal seaweed productivity, which is total seaweed production with the application of Kajarula technology can reach 7.54 ± 0.27 kg/unit, with relative growth of 153.41 ± 10.97 %/day, and growth of 239.32 ± 21.95 g/day.

4 Conclusion

Applying Kajarula technology to the productivity of Kappaphycus striatus seaweed at Tablolong Beach, West Kupang, East Nusa Tenggara, showed optimal yields. The production performance of seaweed cultivated for 42 days resulted in an average biomass production of 7.54 ± 0.27 kg/units with an average relative growth of 153.41 ± 10.97 %/day, a growth rate
of 239.32 ± 21.95 g/day, and a total harvest of 5.82 – 7.45 kg/units. In addition, the water quality conditions during the rearing period were in the optimum range to support seaweed growth.

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