Evaluation Of Different Culture Methods On The Growth Performance Of Seaweed (*Kappaphycus striatum*) In Pelakak Village Waters Lingga District

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Abstract. The seaweed culture activities are relatively new and only few people perform them in Lingga District. Specifically, *Kappaphycus striatum* has recently been cultured for the last three culture periods. This condition causes the seaweed culturists have no appropriate data associated with a proper culture method, following the water characteristics around the culture area. A study regarding the different culture methods on the growth performance of *K. striatum* in Pelakak Village waters, Lingga District, Riau Islands has never been reported. This study aimed to determine the effect of different culture methods on the growth performance of *Kappaphycus striatum* seaweed. This study used a completely randomized block design with three treatments and three replications, namely bottom method (P1), off-bottom (P2), and longline method (P3). There were 351 seaweed seeds with 100 g weight per each seed, that are placed in nine culture plots. The culture plot was constructed as a 4 m × 1.5 m square with wooden stakes at both ends and polyethylene ropes installed at a distance of 0.5 m. Each rope stretch was tied at 0.3 m distance for seed planting. Parameters observed in this study were absolute growth rate, specific growth rate, and production rate of the seaweed. The results showed that the absolute growth rate, specific growth rate, and production rate were affected by the culture method ($p<0.05$). The seaweed group reared in a longline method (P3) obtained the best results, compared to other methods, at 2.34% per day for specific growth rate and 245.7 g/m^2 for production rate. Therefore, the longline method can be applied in the Pelakak Village waters, Lingga District.

1 Introduction

Seaweeds are included in Thallophyte division and Algae sub-division. Seaweeds are macroalgae that can conduct photosynthesis due to possessing chlorophyll contents. These plants are grouped as lower plants without true roots, stem, and leaves. Seaweeds have thallus that likely appears as a stem in higher plants. Seaweeds can be consumed by humas and utilized for various industries, including medicines, cosmetics, paint, textile, food processing, and agriculture. Seaweeds contain many benefits: (1) Having various essential mineral contents, such as iron, soluble nitrogen, phosphorous, sulphur, chloric, potassium, iodine, calcium, cobalt, boron, and copper, (2) High protein, nucleic acids, amino acids, starch, sugars, and vitamin A, B, C, D, E, and K [1].
Indonesia is the second largest exporter of seaweeds after China. The Indonesian export value of seaweeds by October, 2021 is USD 177.9 millions [2]. Thus, the seaweed culture is highly potential for the coastal community, especially in the Riau Islands, as 95% of the area is covered with the sea.

Several seaweed culture methods have been well-known and applied in Indonesia, namely (1) bottom, (2) off-bottom, and (3) longline methods. Studies regarding the different culture methods on the growth performance of seaweeds have many been performed in other locations with different results. For example, [3] showed that different culture methods affected the absolute and specific growth rates of seaweeds, but [4] stated in a contradiction. Furthermore, the highest specific growth rate was reported in the off-bottom method [5]. The longline method had a higher production value than the floating method [6]. The specific growth of seaweeds cultured in an off-bottom method was higher than in a longline method and a bottom method [7]. (Alimuddin, 2013)
The seaweed culture activities are still new and few people perform them in Lingga District. Specifically, the *Kappaphycus striatum* seaweed culture has only been cultured in the last three culture periods. Thus, there are no representative data on the growth rate and production of *K. striatum* seaweed cultured by the community. Also, there are no scientific reports on the effect of different culture methods on the growth performance of seaweeds in Lingga District waters, Riau Islands. This condition means that the culturists have no proper culture method choice, according to the characteristics of the waters in their area.

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In addition, the influence of season on seaweed growth performance is also unknown. There are four wind seasons known to the culturists in this area, namely the west, north, east and south winds. The speed and direction of the wind in each season is different, which affects the speed of sea water currents and water quality. Based on [8] (Akmal et al., 2013) and [9] (Hamzah, 2022), the external factors that influence the growth of seaweed are the physical and chemical environmental conditions of the waters and the correlation with current speed, dissolved oxygen, and temperature. Therefore, a study following this aspect is necessary to support the industrialization plan for seaweed culture in Lingga District. This study aimed to: (1) identify the effect of different culture methods (bottom, off-bottom, and longline) on the seaweed growth performance, (2) select the best culture method for seaweed.

2 Methods

This study was performed on July – September, 2023 in Pelakak Village, Lingga District. Materials and equipment used in this study were seaweed seeds, water quality checker, seawater, digital scale, PE rope with 2, 4, 6 mm diameter, and speedboat.

2.1 Experimental design

Based on the methods and construction units of culture plots created as treatment groups, the experiment was classified as a randomized block design. There were three culture methods applied with three replications. The culture methods were:

(1) Bottom method with 100 g seeds/clump (P1),
(2) Off-bottom method with 100 g seeds/clump (P2), and
(3) Longline with 100 g seeds/clump (P3)

2.2 Procedures

The location for placing the culture plots were established in an area that has been empirically used for seaweed culture owned by the local community. Geographically, the seaweed culture experiment was located on 104.4910 E dan 0° 21’0”S, as shown in Figure 1.

Fig. 1. Seaweed culture plot location in Pelakak Village, Singkep Pesisir Sub-district, Lingga District

2.3 Culture plots and seaweed seeds preparation

The culture plot was constructed in a square shape, prepared by the following procedure:

(1) Prepare wooden stakes with a diameter of 4-5 cm and a length of 1.3 m, then sharpen the stakes at one end. Take two wooden stakes and stick them both at a distance of 4 m parallel to the current direction.
(2) Insert two wooden stakes again in the same way as previous in the position next to the stakes that have been stuck. Install the next stakes next to it parallel to a distance of 50 cm.

(3) Tie and connect the stakes using 6 mm PE rope at a height of 10 cm from the bottom of the water at low tide and 20 cm from the water surface.
(4) Tie a 2 mm PE rope (can be replaced with raffia rope) to tie the seeds to a 4 mm PE rope with a distance of 30 cm between the seed ties.
(5) Stretch a 4 mm PE rope containing seaweed seeds on the two stakes (from stake A to stake B) at a height of 10 cm (bottom method), 30 cm (off-bottom method) from the bottom of the water, and 20 cm from the water surface for longline method, then tie a 4 mm PE rope tightly.

2.4 Monitoring the growth and health, and seaweed sampling

The seaweed seeds condition in the culture plots were monitored every day for a week to clean up rubbish that may be stuck in seed clumps or in PE ropes. The first sampling was carried out once a week. Harvesting was performed on the 45th day of culture.

2.5 Parameters

The parameters measured were composed of (a) absolute growth rate, (b) daily growth rate, and (c) total biomass production of the seaweeds. The formulation used for each parameter is:

$$\text{Absolute growth rate (W)} = Wt - Wo \qquad (1)$$

Note:
Wt = final seaweed weight (g)
Wo = initial seaweed weight (g)

$$\text{Daily growth rate (\%/day)} = [Wt - Wo)/t] \times 100 \qquad (2)$$

Note:
Wt = final seaweed wet weight (g)
Wo = initial seaweed wet weight (g)
t = maintenance period (day)

$$\text{Productivity (kg m}^{-2}\text{)} = (Wt - Wo)/L \qquad (3)$$

Note:
Wt = final (harvested) seaweed weight (kg)
Wo= initial seaweed weight (kg)
L = maintenance area (m^2)

3 Data analysis

Seaweed growth data was analyzed with an analysis of variance. If the results were significantly different, then the analysis was continued with the Duncan's test at a confidence level of 95%. Data on the physical, chemical and biological quality of waters were presented descriptively and were analyzed based on the Indonesian national standards (SNI) and reputable journals.

4 Results and discussion

Growth rates and production rate

The amount of absolute growth rate, specific growth rate, and land productivity in each treatment is presented in Table 1, 2, and 3.

Table 1. Absolute growth rate of seaweeds

No	Treatment	Average final weight (g)	Absolute growth rate (g)

1	Bottom	138.03 ± 5.69	38.03
2	Off-bottom	141.17 ± 4.38	41.17
3	Longline	149.14 ± 7.80	49.14

Table 2. Specific growth rate of the seaweeds

No	Treatment	Specific growth rate (%/day)
1	Bottom	1.81
2	Off-bottom	1.96
3	Longline	2.34

Table 3. Biomass production of seaweeds and productivity level for 21 days of maintenance

No	Treatment	Biomass production (g)	Productivity (g/m^2)
1	Bottom	1140.8	190.13
2	Off-bottom	1235.2	205.86
3	Longline	1471.2	245.7

Tables 1, 2 and 3 present the absolute growth rate, specific growth rate, and production rate of *Kappaphycus striatum* seaweed cultured using the longline method (P3) at 49.14 g, 2.34%/day, and 245.7g/m^2, respectively. A higher growth rate of seaweeds in longline method than in two other methods was occurred due to the plotting depth of the seaweeds in the waters and the sunlight intensity received by the seaweeds. One of the essences that differentiates the three cultivation methods is actually the depth difference at which seaweed seeds are laid, calculated from the water surface. Seaweeds in the longline method is closer to the water surface than the off-bottom and bottom methods. This position causes seaweed cultured in the longline method can receive the most sunlight intensity, producing a better growth rate. This statement was in line with [10], who stated that the growth rate of seaweeds is different due to different sunlight intensity received, following the depth differences. Seaweed growth is generally better in shallow water, associated with high light intensity level, but it should not be too shallow because it will cause the water to become easily turbid [11].

The water depth where the seaweed was maintained during high tide was generally more than two meters, so the seaweed in the off-bottom and bottom methods did not receive optimal sunlight, compared to the longline method. [12] stated that seaweed growth in open water should be best maintained at 1.0 m depth. [13] argued that the total light intensity at 20 cm depth was 317 µmol $m^{-2}s^{-1}$ and 100 cm depth was 298 µmol m^{-2} s^{-1}. The maximum seaweed growth rate was achieved at a light intensity of 8.4 µmol $m^{-2}s^{-1}$, then decreased at 14 µmol m^{-2} s^{-1}. Therefore, the thallus growth tends to be greater and longer than seaweeds cultured in a place more closed to the water surface. Apart from the sunlight intensity, seaweed growth is influenced by currents. The current at 20 cm depth is 0.2-0.3 m/sec. Nutrients in water bodies for growth are collected by seaweed through their thallus walls by diffusion [14]. The nutrient diffusion will be greater, if the water movement is greater. This situation accelerates the seaweed metabolic process, speeding up its growth [10]. However, it is suspected that if the current is too strong or more than 0.5 m/sec, the seaweed growth tends to be detrimental.

The seaweed specific growth rate in the longline method tends to be higher and almost similar to [15] at 2.26% - 3.47%/day. This growth can be higher, if there are no epiphytic organisms attacking the seaweed surface (host), such as red filamentous algae (Epiphitic Filamentous Algae/EFA) from *Melanothamnus* sp. (formerly called as *Neosiphonia* sp.), and ice-ice disease.

The epiphytic algae, *Melanothamnus* sp., uses its rhizoids to penetrate the host cortex and medullary tissue. The seaweed morphology attacked by this epiphyte in the early stages are presented with black spots, followed by the development of red hair-like filaments. The seaweed tissue cells disintegrate, forming cavities or pores that make them more susceptible to secondary or multiple infections. The thallus becomes weakened, then breaks from the culture rope and floated away. This infection has the potential to reduce photosynthetic activity and nutrient absorption in seaweed, but can also be a disease precursor [16].

The *Melanothamnus* sp. attacking level was highly effective in seaweeds cultured using bottom and off-bottom methods, compared to the longline method. This condition was occurred because both methods are closer to the substrate/bottom of the waters, which are rich in organic material as the preferred substrate for *Melanothamnus* sp. In this study, all seaweed clumps in the bottom and off-bottom methods were attacked by the epiphyte *Melanothamnus* sp. and 5% of them were affected by the ice-ice disease, while 90% of the seaweeds in the longline method were affected by *Melanothamnus* sp., as shown in Figures 2 and 3.

Figure 2. *Melanothamnus* sp. on seaweeds cultured in bottom method

Figure 3. Epiphyte *Melanothamnus* sp. that has been separated from *K. striatum* and placed on the hands. This epiphyte has still many been attaching to the seaweeds

Figure 4. *K. striatum* seaweeds suffered from ice-ice disease showing white-colored thallus

According to the [17], *Melanothamnus* sp. can be controlled by separating the infected seaweed from non-infected seaweeds, using superior seaweed seeds, moving the culture location, choosing the right location and culture time. For ice-ice disease prevention, the following steps are required: Disinfection with $KMnO_4$, use of superior seeds, selection of proper location and culture time.

Water quality of the waters as a seaweed culture location is presented in Table 4.

Table 4. Water quality of the seaweed culture location in Pelakak Village Lingga District

No	Parameter	Value	National Standard (SNI 7673 :2.2011)	Status
1	Temperature (°C)	27.8-29.1	24-32	Complied with the standard

2	Salinity (ppt)	30.1-31.2	28-33	Complied with the standard
3	pH	7.2-7.34	7-8.5	Complied with the standard
4	Current speed	0.5 m/sec.	20-40 cm/sec.	**Uncomplied** with the standard

Table 4 describes that the relative current speed in the south wind season when the experiment was conducted exceeded the SNI standard, which was classified as highly fast at >0.5 m/sec. As a result, the seaweed thallus could break easily and was carried away by the current.

5 Conclusion

The culture methods can influence the seaweed growth performance. The longline method provides the best seaweed growth performance, compared to the bottom method and the off-bottom method.

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