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Growth Performances and Productivities of *Kappaphycus alvarezii* and *Eucheuma spinosum* Cultivated with Long-line Method in PT. Sea Six Energy Indonesia

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Abstract

Indonesia is the second largest producer of seaweed in the world. Different cultivated seaweed commodities may have different production results. This study aimed to determine the effect of cultivation time and different types of seaweed on the total weight and Specific Growth Rate (SGR) of *Kappaphycus alvarezii* and *Eucheuma spinosum* cultivated with the long-line method. The study was conducted in one cultivation area, PT. Sea Six Energy, Bali, Indonesia. Data collection was carried out through observations in 2 sites. Every site contained 3 square frame seaweed *K. alvarezii* and *E. spinosum*. The sample used in this study was one thallus of seaweed taken randomly from 3 different ris ropes in each square frame. The average weight of thallus, total weight, and specific growth rate were performed in this study. After 51 days, the total weight of *K. alvarezii* was 1348.5 kg. The total weight of *E. spinosum* was 1398.7 kg. Both, *K. alvarezii* (8.4 ± 0.34 %.day^{-1}) and *E. spinosum* (8.3 ± 0.02 %.day^{-1}) showed higher Spesific Growth Rate (SGR) in the first 2 weeks of planting but not in the last 3 weeks of cultivation. There was no difference in productivity between K. *alvarezii* and E. *spinosum* cultivated using the long-line method. However, this research showed that the SGR value decreased as cultivation time increased.

INTRODUCTION

Seaweed production in Indonesia is the second largest global production following China and contributed over 38,7% (11,6 million tonnes) in 2016 (FAO, 2018). Indonesia mostly cultivates the seaweed species *Eucheuma* spp., *Kappaphycus* spp., and *Gracilaria* spp. (Purnomo *et al.,* 2020). *K. alvarezii* is a type of seaweed that produces carrageenan, specifically kappa carrageenan. Seaweed is known to be a good source of dietary fiber (78.94%) and vitamins A (beta-carotene), B1, B2, B6, B12, C, and niacin, as well as important minerals such as calcium and iron (Tamaheang *et al.,* 2017). High concentrations of dietary fiber, minerals, vitamins, antioxidants, polyphenols, phytochemicals, proteins, polyunsaturated and fatty acids, and other components found in *E. cottonii* may have therapeutic use (Setyorini *et al.,* 2017). Based on previous research, there are differences in growth between two different types of seaweed,

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between *K. alvarezii* and *Gracilaria* (Hernanto *et al.*, 2015) and between *E. spinosum* and *E. cottonii* (Wiyanto, 2014).

The success of seaweed production can be achieved by optimizing the supporting factors in marine cultivation. These supporting factors include selecting the right cultivation location, using high-quality planting seeds, and appropriate cultivation techniques or methods. The long-line method is a method of cultivating seaweed in the euphotic zone near the surface of the water using a line that is stretched from one point to another with a length of 25-50 m, in the form of a loose lane or linked with the help of buoys and anchors (Hernanto *et al.*, 2015). As for several water quality parameters that support seaweed life based on SNI (2015), the temperature ranges from 26-32°C, the pH ranges from 7.0-8.5, and salinity ranges from 28-34 ppt. The dissolved oxygen value is 4.5-9.8 mg/l. A good current speed for seaweed cultivation is 20-40 cm/second (Asni, 2015), a suitable nitrate range for seaweed growth is 0.9-3.5 mg/l (Hasan *et al.*, 2015) phosphate ranges from 0.021-0 .10 mg/l (Indriyani *et al.*, 2021).

The planting distance is strongly related to this method. Additionally, it enables the seaweed to use nutrients from the water current and sunlight for photosynthesis to their fullest potential. Proper cultivation methods are necessary for seaweed production to be successful (Husniah *et al.,* 2020). Therefore, This study aimed to determine the effect of cultivation time and different types of seaweed on the total weight and Specific Growth Rate (SGR) of *K. alvarezii* and *E. spinosum* cultivated with the long-line method. This study is expected to be beneficial as a reference for farmers and the community in cultivating *K. alvarezii* and *E. spinosum* seaweed with the long-line method.

METHODOLOGY
Ethical Approval
This study used seaweed seeds for plants and then analyzed their growth. Therefore, this study used no animals living.

Place and Time
This research was conducted in February – April 2023 at PT. Sea Six Energy Indonesia, Patas Village, Gerokgak, Buleleng, Bali. The location map of seaweed cultivation can be seen in Figure 1.

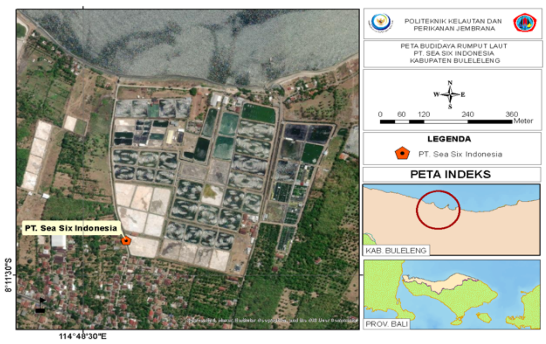

Figure 1. The location of seaweed cultivation at PT. Sea Six Energy.

Research Materials
The tools needed in this research were boats, iron, anchors, swimming buoys, plastic tarps, polyethylene ropes, para-para (seaweed drying place), scales (manual hanging scales and digital scales), plastic buckets, and cleavers. The materials needed in this research were seaweed seeds of *K. alvarezii* and *E. spinosum*.

Research Design
Data collection was carried out through observations in 2 sites. Every site contained 3 square frame seaweed *K. alvarezii* and *E. spinosum*. The sample used in

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this study was one thallus of seaweed taken randomly from 3 different ris ropes in each square frame. Sampling for SGR was conducted once, every two weeks. Total weight was collected at the end of the study. Three plots were taken from each site to observe. The Specific Growth Rate was calculated using a formula according to Luhan and Sollesta (2010):

$$SGR = \left(\frac{\ln_{Wt}}{\ln_{Wo}}\right) x100\%$$

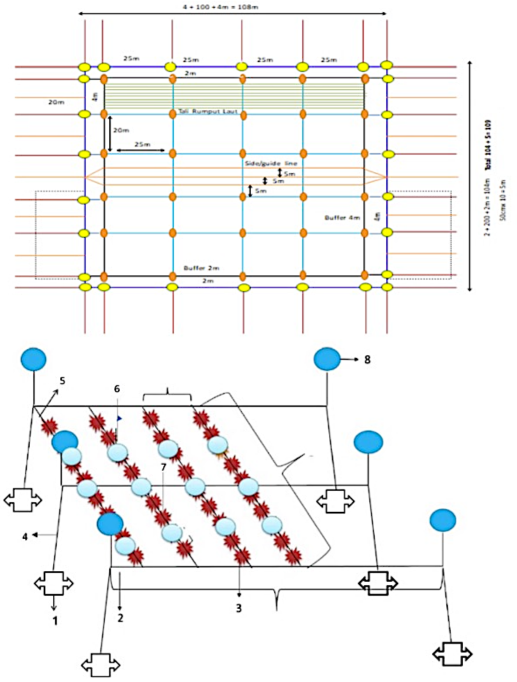
where

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

Work Procedure

Preparation of Long-Line Construction

The Long Line method is cultivating seaweed in the water column (euphotic) near the water's surface with a rope that stretches from one point to another with a length of 25-50 m in the form loose lane or set (Ariyati *et al.,* 2016). Long Line construction materials at PT. Sea Six Energy Indonesia had anchors, polyethylene ropes, and floaties with sizes 100 m x 100 m. It used 86 anchors, at each end of the ropes contained 2 anchors. The horizontal side contained 24 anchors, at the vertical side contained 10 anchors. The ropes for anchors were polyethylene (diameter 10 mm). The ropes for seaweed were 4 mm with 25 meters in length. The main ropes were 12 mm in diameter. The long-line construction can be seen in Figure 2.



Legend :
1. Iron anchor
2. Main rope
3. Seaweed
4. Anchor rope
5. Ris rope
6. Small buoy
7. 2 mm rope
8. Large buoy

Figure 2. Long-Line Construction at PT. Sea Six Energy Indonesia from above (upper) and side (bottom).

Seaweed Seeds Preparation

The good quality of seaweed seeds impacted seaweed cultivation results. Seaweed seeds were from a subsidiary company in Lombok, Nusa Tenggara Barat, or from Alasrejo, Situbondo. PT. Sea Six Energy Indonesia selected seeds by considering some characteristics such as seeds seaweed chosen were seeded was in 30-35 days, not afflicted, thallus much, and not slimy. The seeds that were chosen to cultivate had good quality, did not have some diseases, and were branchy. This is to the requirements of good seaweed seedlings. The seed should have a uniform look and not be intermingled with other varieties. It

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should have a cylindrical rod or tallus appearance, be clean, fresh, hard, not slimy, not fishy-smelling, and not pale (Rahim, 2018). The seeds were delivered using open-tub trucks and the seeds were put into sacks. During the delivery process, seeds must not be directly exposed to sunlight, neither fresh water nor rain because it causes seaweed to be damaged or to die.

Handling seeds started when seeds arrived in PT. Sea Six Energy Indonesia. When seeds arrived in the morning until noon, seeds could be directly cultivated, whereas seeds that arrived at night, seeds would be soaked in salt water to keep seeds alive. Oedjoe *et al.* (2020), explained when the four sacks were opened after thirty and thirty-six hours, it was evident that the plants had become wilted and that many of them had died. This occurred because the seaweed within each of the four sacks felt a little warmer and was all white and soft when they were opened. While all of the plants in the sacks opened between 30 and 36 hours of life died, the plants in the sacks opened between 6 and 24 hours of life remain alive and exhibit development.

Seaweed Seeds Binding

Seed binding was carried out in the seashore close to the warehouse, using tarps as horses. When the seeds are in 3 weeks or 30 days lived, the seeds could be cut to increased varieties before harvest time. Seaweed seeds would be bonded using a 2 mm rope as a middle rope to connect with 4 mm ropes. Seaweed would be bonded by inserting 2 mm ropes into the cavity of seaweed and then bonded dead knot when bonded seaweed was not allowed death rope because the rope used to tie it will be reused so that the seaweed to be tied can be easily detached. Seaweed seedlings were tied at intervals of 10 to 12 cm, depending on the rope ordered by the company. Seaweed seedlings that have been tied would then be weighed to determine the weight of the seedlings before being planted by workers.

Seaweed Seeds Planting

Planting of seaweed seedlings was carried out when the seedlings had been cut and tied, and then the seedlings were planted in the sea. The optimal time for planting seaweed at PT. Sea Six Energy Indonesia was in the morning and evening because the temperature was relatively lower than in the afternoon. The main rope would be tied to the main rope measuring 10 mm, then the main rope would be stretched horizontally at a distance of about 1 meter from the previous main rope. This was intended so that when large waves came, seaweed did not tangle with each other, making it difficult for workers during planting, land clearing, and harvesting, and also resulting in suboptimal seaweed growth.

Data Analysis

All data obtained were tabulated using Microsoft Excel 2010. The growth performance observed in this study was Specific Growth Rate (SGR). Productivities were observed with the Total Weight of *K. alvarezii* and *E. spinosum*. Growth performance parameters were analyzed through ANOVA, followed by the Duncan test with a confidence level of 95% (a=0.05). Water quality parameters were presented using descriptive statistics.

RESULTS AND DISCUSSIONS

Growth Performance

Average Weight of Thallus

Observation of *K. alvarezii* and *E. spinosum* has been conducted over 51 days, once every week the thallus weight growth was measured. The average thallus weight of *K. alvarezii* for four weeks was 43.3±2.5 kg, 58.1±4.9 kg, 71.5±5.4 kg, and 86.5±5.4 kg, respectively. The average thallus weight of *E. spinosum* was 38.3±2.5 kg, 53.0±2.3 kg, 66.7±3.8 kg, and 80.7±3.8 kg. Based on the statistical analysis, between two species of seaweed had no significant result in the weight of thallus. This study showed a different result from Wiyanto (2014) explained that *E. cottoni* (former name of *K. alvarezii*)

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grew faster than *E. spinosum* for 40 days of planting. The average weight of Thallus on *K. alvarezii* and *E. spinosum* is presented in Figure 3.

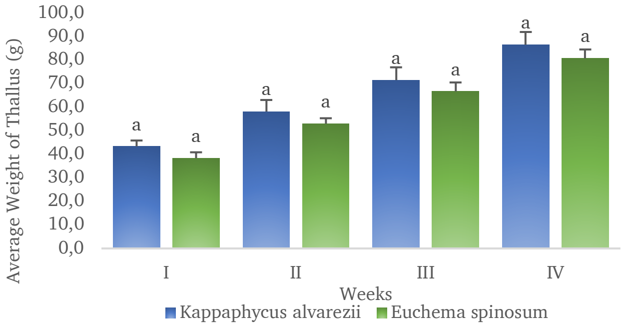

Figure 3. The average weight of thallus on long-line at PT. Sea Six Energy Indonesia.

Total Weight

Harvesting in PT. Sea Six energy was done when the seaweed is more than 45 days old or when the seaweed is heavily attacked by diseases. The total weight in this study was observed for 51 days. The growth of *K. alvarezii* increased from 89.3±8.17 kg to 449.5±18.2 kg and from 94.9±0.7 kg to 466.2±17.8 kg in *E. spinosum*. Between the two species of seaweed, there was no significant result in the total weight. Harvesting was done in the morning or afternoon, by releasing the knot of the "*ris*" line on the main line knot and then pulling the ris line up to the boat. The seaweed that has been on the boat is then twisted by hand and then put into the harvest bag. The total weight growth of *K. alvarezii* and *E. spinosum* seaweed is presented in Figure 4.

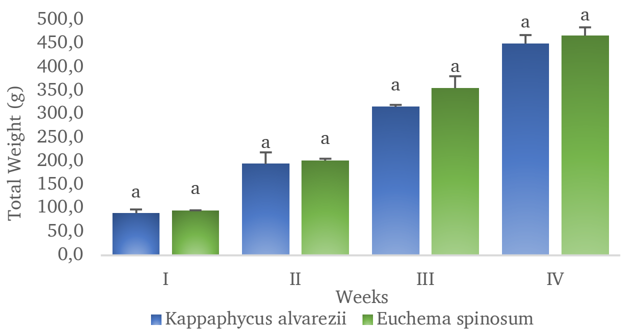

Figure 4. Total Weight of *Kappaphycus alvarezii* and *Eucheuma spinosum*.

The interactions between sunlight, temperature, nutrients, and water flow determine how quickly seaweeds grow. A species' ability to grow may be influenced by certain of these interactions, and the depletion of one item (nutrients, for example) may be offset by the movement of water. The flow of water that provides nutrients to the seaweeds can be impacted by spacing. The increased width of the row spacing improves the flow of the water stream that carries nutrients, enabling the thallus to absorb enough of those nutrients for photosynthesis (Herliany *et al.,* 2016). Based on the results, the total weight of the harvest for seaweed cultivation activities at PT.Sea Six Energy was obtained, with a total weight of 1348.5 kg for the *K. alvarezii*, and *E. spinosum* was 1398.7 kg.

Specific Growth Rate

Specific Growth Rate in this study was observed over 51 days. The specific Growth Rate appears to decline with time. Both, *K. alvarezii* (8.4 ± 0.34 $\%.day^{-1}$) and *E.*

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spinosum (8.3 ± 0.02 %.day^{-1}) showed higher SGR in the first 2 weeks of planting. The lower SGR result was in the last 3 weeks of cultivation, both in *K. alvarezii* (4.8 ± 0.02 %.day^{-1}) and *E. spinosum* (4.8 ± 0.03 %.day^{-1}). At the end of cultivation (51 days), SGR decreased by 61.8% (*K. alvarezii*) and 60.2% (*E. spinosum*) from previous sampling in 28 days of cultivation by 93.3% (*K. alvarezii*) and 95% (*E. spinosum)*. Based on the statistical analysis, different types of seaweed had no significant effect on SGR. The SGR of *K. alvarezii* and *E. spinosum* seaweed is presented in Figure 5.

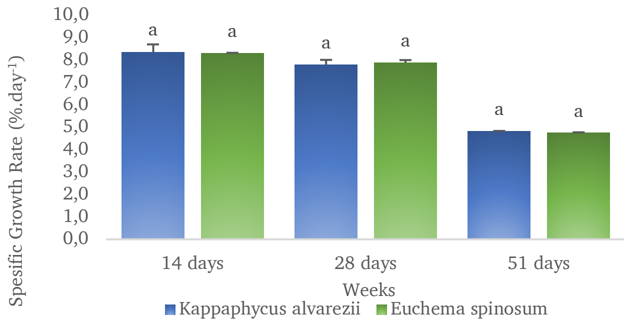

Figure 5. Specific Growth Rate of *Kappaphycus alvarezii* and *Eucheuma spinosum*.

The results of the specific growth rate observation in this practical activity were more than 3.3%, which is supported by the statement of Anggadiredja *et al.* (2006) that plant growth is considered good if the daily growth rate is not less than 3%. In another opinion, as stated in Ismail *et al.* (2015), it is also explained that the daily growth percentage of seaweed is around 2-3% per day. Lobban and Paul (2000), explained that the factors that affect seaweed growth are age, phenotype, genotype, reproductive conditions, and nutrients in the water.

Water Quality

This study was conducted in one cultivation area with the same environmental parameters. Water quality parameters such as temperature, water current, brightness, salinity, and pH were measured. The temperature of the sea is influenced by sunlight and the temperature changes. From the table, the temperature obtained between 28 - 30°C. Overall, the temperature at the study sites was suitable for seaweed cultivation. The role of currents is to clean seaweed from dirt and distribute nutrients to seaweed. A clean thallus surface will make it easier for seaweed to absorb nutrients and sunlight so that photosynthesis can take place optimally (Fikri *et al*., 2015). The water quality obtained in this study is presented in Table 1.

Table 1. Water quality measurement in the cultivation area of K. *alvarezii* and E. *Spinosum*.

Parameter	Range Value	Standard	References
Temperature (^{0}C)	28-30	26-29	Nur *et al.* (2016)
Water Current (m/s)	0,06-0,17	0,2-0,4	Nikhlani and Kusumaningrum (2021)
Brightness (m)	3	<5	Nikhlani and Kusumaningrum (2021)
Salinity (ppt)	29-35	32-35	Parenrengi *et al.* (2011)
pH	7,5-8,5	6,5-9	Nur *et al.* (2016)

From the table, the minimum current speed of 0.06 m/s, and the maximum speed of 0.17 m/s. Salinity during cultivation at PT. Sea Six Energy Indonesia was in the optimal value, between 29-35 ppt. Variations in pH values greatly influence the life of aquatic biota (Hamuna *et al*., 2018). The data showed the pH ranges from 7.5 – 8.5.

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This pH value was suitable for seaweed cultivation activities.

CONCLUSION

Differences in species with the same cultivation methods did not provide differences in growth rate. However, this research showed that the SGR value decreased as cultivation time increased. SGR decreased 61.8% (*K. alvarezii*) and 60.2% (*E. spinosum*) from previous sampling in 28 days of cultivation 93.3% (*K. alvarezii*) and 95% (*E. spinosum*). Water quality measurements indicate that the study site is generally suitable for seaweed growth.

CONFLICT OF INTEREST

There is no conflict of interest in this manuscript between all authors upon writing and publishing this manuscript.

AUTHOR CONTRIBUTION

The three authors collected data, measured, and wrote on this manuscript.

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