Intensification of Seaweed Cultivation Euchema cottonii with Verticulture Method in the Water of Kelagian Island, Lampung Bay

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Intensification of Seaweed Cultivation *Euchema cottonii* with Verticulture Method in the Water of Kelagian Island, Lampung Bay

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Abstract *E.cottonii* production is not still optimal and there are opportunities to increase production by developing methods that to utilize the depth level as a growing medium. Method of verticulture cultivation with pocket nets, more innovative and have high production level. This study aimed to solve the problems in seaweed cultivation by optimizing the land. Design of vertical cultivation model *E.cottonii* in Kelagian Island using bamboo raft and made up by 15 points on each of the 10 depth levels (BRL); 0, 70, 140, 210, 280, 350, 420, 490, 560 and 630 cm from the surface. Environmental parameters and seaweed are measured weekly. This study measures daily, weekly, absolute growth and total production. Data were analyzed by cruciate-wallis test. The results showed that the physico-chemical parameters of the waters were suitable for the cultivation of *E.cottonii*, except for the nitrate contents and current which were below the optimum value. The largest average weekly growth showed on the BRL 1 with 118.08 g and the smallest on BRL 10 with 107.41 g. The absolute greatest growth rate showed on the BRL 1 weighs 145.33 g and the lowest on BRL 10 with 130.67 g. The highest daily growth on BRL 1 with 1.59% / day and the lowest at BRL 10 with 1.33% / day. The total of *E.cottonii* production cultivated showed BRL 1 - BRL 10 of 20744 g (20.744 kg), the highest total production at BRL 1 with 2180 g and the lowest BRL 10 by 1960 g. The kruskall-wallis analysis were showed about 21.837 (H_{count}) and 23,685 (H_{table}), where it's not influence of depth level (BRL) for seaweed grown.

Keywords Verticulture; Kelagian Island; Cultivation; Seaweed and *E.cottonii*

Background

Indonesia as an archipelagic country with a total of 13,466 islands and a coastline length of more than 81,000 km has enormous potency for the development of seaweed commodities. The indicative land area can be used for the cultivation of Indonesian seaweed commodity reaches 769,452 ha. That number, only about 50% or an area of 384,733 ha which is effectively utilized (Sahat, 2013). One of the potential seaweed jeans to continue to be developed is Kappaphycus alvarezii (Doty). Philippine and Indonesia are the two major producing countries of k-carrageenan in the world market (Adnan and Porse, 1987). Over the last 30 years, *K. alvarezii* and *Kappaphycus striatum* (Schmitz) Doty from the Philippines have been introduced to more than 20 tropical countries for cultivation purposes (Glenn and Doty, 1990; Areces, 1995).

The need for seaweed with good quality, high productivity and sustainable is still a homework that can't be fulfilled until now. Indonesia is a major seaweed producing country. Currently the high demand can be filled by the natural harvest (natural stock) and the cultivation. Seaweed cultivation sector can still be increased again in line with the need and availability of sufficient land. The development and improvement of seaweed production can be fulfilled from the cultivation intensively and extensively.

Seaweed cultivation is generally done in relatively calm and closed (protected) waters like in the bay, behind an island. But the calm, sheltered waters are very hard to find. Even if there is still such land, a lot of fishermen who conduct cultivation activities such as pearl shells, karamba, seaweed and so on. So it needs a breakthrough by doing extensification and intensification simultaneously of land in seaweed cultivation into waters that are still undeveloped for cultivation (Aslan, 1998; Hendri, 2009; 2015).

The success of cultivation depends on several factors, namely; Seasons, land suitability, planting methods, seedlings and post-harvest. Seaweed cultivation method *E.cotonii* is generally done by using raft, off base and long line. Horizontal long line method can be built very long reaching kilometers so that its existence can disrupt the cruise line. In addition, the use of such methods in open water is very vulnerable to production failures caused by limitations in control and environmental factors, one of which is the attack of herbivorous seaweed-eating animals such as *Siganus* Sp (beronang), turtles, abalone and sea urchins. Meanwhile, the utilization of the water column (vertikultur) has not been fully utilized.

Verticulture method is a method of planting seaweed in a vertical way at depth by utilizing the water column as a medium. The depth of the water used may vary according to the sunlight penetration capability. This method is utilized by considering the optimization of the land and the utilization of the water column. Utilization of this method is expected to intensify land use and increase seaweed production.

Verticulture method is done by tying the seed of seaweed in a vertical position (perpendicular) on the ropes arranged in a row. This method can utilize the water column up to the water brightness limit. According to Aslan (1998) and Syahlun (2013) the penetration of sunlight as a condition of producing seaweed can be obtained not only from one side of the water surface but from different angles of light elevation. On the other hand, the nutrient content of the waters is in the optimum water column range. Both factors become one of the basic in the application of seaweed cultivation with vertical or vertikultur method. Serdiati and Widiastuti (2012) suggested that seaweed maintained at 100 cm vertical strap lengths still have the effect of optimum current and wave movement for the growth of *E. cottoni* seaweed so as to have a considerable opportunity in nutrient absorption.

Research on the growth of *Euchema cottoni* at different depths had been done also by Naguit et al. (2009), the obtained result was the best growth with growth rate of 2.85% with carrageen content 81,74%. Meanwhile, according to Syahlun (2013) the specific growth rate in verticulture method showed a real effect, carrageen content of K. alvarezii seaweed on verticulture method did not show any significant or no significant effect. While Safarudin (2011) get results at a depth of 30-120 cm provides a high response to growth. At this depth the seaweed can still grow well because of the presence of sunlight that enter into the waters and the movement of water that carries the nutrients needed by seaweed.

The selection of wavy and bumpy cultivation locations has an influence on the growth rate of seaweed. The result shows that the planting of seaweed Cidaun model has a slower rate on the type of waters that have waves and small waves (Susanto, 2005). This condition is as a result of the attachment of substrate and epiphytic biota so that it can inhibit the growth rate. The method of floating raft has better result compared with longline method and basic off method. According to Wijayanto et al. (2014), the relative growth rate in the cultivation of *E.cottonii* in Lampung Bay by raft method is about 1.569 g.

The results showed that plant spacing and initial weights of planting had an effect on the growth rate of seaweed. The result of research of Pongarrang et al. (2013) on the best vertical plant spacing method is 40 cm with the initial weight of 100 g seedlings. Meanwhile, according to Herliany et al. (2016), the wider the spacing will produce wet weight and greater relative growth. Planting distance 30 cm better than plant spacing of 20 cm and 25 cm. Farman and Ilham (2015) stated that spacing has an influence on seaweed growth. The best planting distance is 120 cm from the spacing of 30 cm, 45 cm, 75 cm, 90 cm and the initial weight of 100 g on the cultivation of *Sargassum* sp with the basic off method. Meanwhile, according to Darmawati (2013), the average daily growth rate is at 50 cm (4.750%), higher than the daily growth rate of 20 cm (4.427%), and at 100 cm (3.892%).

The cultivation model used in this research uses raft at various depth level (vertikultur). The cultivated seaweed is not tied but inserted in a specially designed bag of nets to prevent the cultivated *E.cottonii* seaweed from being broken, crashed and damaged by waves, wave and currents. In addition, the developed cultivation model is not planted conventionally but vertically by utilizing water depth / water column as the medium.The purpose of this research is to analyze the physics-chemical parameters of seaweed cultivation of *E.cottonii* verticulture method. Designed model of multi-storey rack with bag net for seaweed cultivation *E.cottonii*. Know and analyze the daily

growth rate, weekly and absolute growth of seaweed E.cottonii by the method of multilevel shelf with bag net model. Calculate and analyze total seaweed production verticulture method. This research is expected to contribute in the form of information to the community about the method of verticulture cultivation. It is hoped that the public can use water column to cultivate seaweed so as to produce maximum product.

1 Materials and Methods

1.1 Research methods

This research was conducted from September to November 2017. The location of the research was conducted in Kelagian Island, Lampung Bay, Indonesia.

1.2 Research design

The treatment carried out in this research is the planting of seaweed by using a combination of depth level up to 10 levels (BRL 1 - BRL 10) with a spacing of 70 cm (vertical). While the spacing is horizontally is 40 cm. Combination of treatment in research:

A. Seaweed seed 1 (BRL 1) is grown at a depth of 0 m (near the surface).
B. Seaweed seed 2 (BRL 2) is grown at a depth of 70 cm from the surface.
C. Seaweed seed 3 (BRL 3) is grown at a depth of 140 cm from the surface.
D. Seaweed seed 4 (BRL 4) is grown at a depth of 210 cm from the surface.
E. Seaweed seed 5 (BRL 5) is grown at a depth of 280 cm from the surface.
F. Seaweed seed 6 (BRL 6) is grown at a depth of 350 cm from the surface.
G. Seaweed seed 7 (BRL 7) is grown at a depth of 420 cm from the surface.
H. Seaweed seed 8 (BRL 8) is grown at a depth of 490 cm from the surface.
I. Seaweed seed 9 (BRL 9) is grown at a depth of 560 cm from the surface.
J. Seaweed seed 10 (BRL 10) is grown at a depth of 630 cm from the surface.

E.cottonii seed (Thallus) to be planted must be shoots and good branching. The treatment conducted in this research is by planting seaweed using a combination of depth level (verticulture) up to 10 levels with the code BRL1 - BRL10 as many as 15 replications. Seed *E. cottonii* inserted in net pocket (net pocket). Spacing used 70 cm (vertical) and 40 cm (horizontal). The vertikultur method with bag net is designed to be resistant to waves, waves and high currents and can optimize land use / utilization. Measurement of environmental parameters and growth of *E.cottonii* is done every 7 days. The cultivation was done for 42 days.

1.3 Variable observed

The data observed in this study are:

Water quality parameters include aquatic physics parameters which include: temperature, depth, current velocity, brightness and chemical parameters such as salinity, nitrate and phosphate.

Weekly Growth Rate (WGR) is the weight of week a, (Wa) is the average weight of week i (Ti) divided by the number of planting point (s) minus the weight of the previous week (Wb), by formula:

$$Wa = \frac{Ti}{\Sigma s} \quad (1)$$

$$WGR = Wa - Wb \quad (2)$$

Absulute Growth Rate (AGR) is the final weight (Wt) reduced by initial weight (Wo), with the following formula:

$$AGR = Wt - Wo \quad (3)$$

Daily Growth Rate (DGR) is the weight of the end (Wt) divided by the initial weight (Wo) the power of a time of planting (t) is reduced by one multiplied by 100%, referring to Gerung and Ohno (1997), Aguirre-von-Wobeser et al. (2001), Bulboa et al. (2007), Hayashi et al. (2007), and Hori et al. (2009) by formula:

$$DGR = \left[\left(\frac{Wt}{Wo}\right)^{\frac{1}{T}} - 1\right] \times 100\% \quad (4)$$

Total Production Rate (TPR) is the final total weight of all planting levels, (Wli) is the total weight of the final point of planting at all the same level, (Wln) plus Total weight of the overall depth level of verticulture cultivation. (Wt) final weight of repeat verticals cultivation i, (Wn) is the final weight of all replicates (Wn), with the formula:

$$\sum Wli = \sum Wi + \cdots + Wn \quad (5)$$

$$TPR = \sum Wli + \cdots + \sum Wln \quad (6)$$

The data obtained tested Normality and HSD (Hadi, 1986; Steel and Torrie, 1993).

2 Results and Discussion

Seaweed cultivation is now one of the mainstays of the government. In 2017 the Ministry of Marine Affairs and Fisheries, Republic of Indonesia (KKP) is targeting 22.6 million tons of seaweed production and it is expected to become one of the world's major seaweed producers. Although Indonesia has the longest coastline in the world but Indonesia seaweed production is not still optimal. One of the obstacles faced by seaweed farmers was disease, continuity of production and limited land. Although it had a long coastline, but not all can be attempted for seaweed cultivation. Seaweed cultivation requires a type of water that is protected from waves and water suitable for cultivation.

Waters with typical big waves and fast-flowing are never used for seaweed cultivation area, whereas the waters are widely found and can increase, accelerate the growth of seaweed. Strong waves and currents in addition to avoiding seaweed from the substrate attached to the thalus are also rich in nutrients needed for growth. In this research, the planting method is designed to resist the waves and fast currents and at the same time can utilize, optimize the utilization and use of land for seaweed cultivation. The developed verticulture method is expected to be more familiar and easy to apply by seaweed farmers. Design and application of raft of vertikultur method can be seen in Figure 1, Figure 2 and Figure 3.

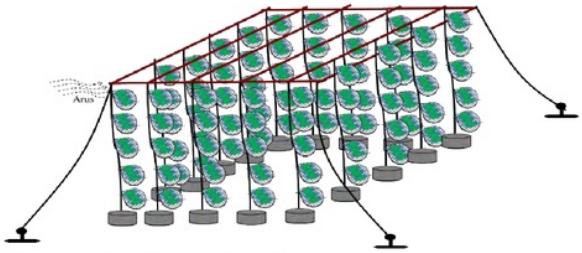

Figure 1 Design of Seaweed Verticiculture *E.cottonii*

Figure 2 Seaweed Verticulture of *E.cottonii*

Figure 3 Seaweed net on vertikultur method

2.1 Physics and chemistry parameters

The result of research were found the physical and chemical parameters of waters is presented in Table 1.

Table 1 Physical-chemical parameters

Temperature (°C)	Salinity (PPM)	pH	Brightness (%)	Current (m/s)	Nitrate (mg/L)	Posfat (mg/L)
29.64	31.57	7.61	100%	0.15	0.35	0.006

Water temperature ranges were about 29-30°C, with an average temperature of 29.64°C There were no striking differences in the measurement of water temperatures during the maintenance period. Water temperature during maintenance period is still good and suitable for seaweed growth. According to Setiyanto et al. (2008), the best water temperature range for *Eucheuma cottonii* seaweed is 27°C-30°C. *E.cottonii* has the optimum temperature for its growth in the range 27°C-30°C (Aslan, 1998). While Munoz et al. (2004) seawater temperature ranged from 28 to 31℃ , with a daily fluctuation range between 25.9 and 31.9°C. Meanwhile, according to BSNI (2010) and WWF (2014), the optimum temperature for seaweed cultivation E.cottonii 26°C-32°C. Optimum temperatures can improve the absorption of nutrients / food, so as to accelerate the growth of seaweed (Effendi, 2003). Water temperature greatly affects the rate of photosynthesis. Each type of seaweed has a range of different temperatures. Temperature is a very important factor. High temperature fluctuations will disrupt metabolic processes. Mixing (mixing) water mass can prevent high temperature fluctuations.

Water salinity ranges were about 31 to 32, with an average salinity of 31.57. There were no significant differences in salinity measurements. Water salinity is within the optimum range for *E.cottonii* growth. Sea organisms have different tolerance ranges of salinity including seaweed. Salinity is one of the important factors that influence the survival and growth of organisms in the ocean. BSNI (2010) mentions good salinity for seaweed growth 28-34. While WWF (2014) mentioned the best salinity for the cultivation of K.alvarezi 27-34.

The pH values range from 7.40 to 8.00, with an average of 7.61. The pH value represents a value that is within a good growth range for *E.cottonii*. Soejatmiko and Wisman (2003) in the paper of Wisnu Ariyati et al. (2016b) mentioned that the appropriate pH range for seaweed cultivation is likely to be alkaline, the pH very suitable for seaweed cultivation is in the range of 7.3 - 8.2. Meanwhile, according to BSNI (2010) and WWF (2014), the suitable pH value for growth is 7-8.5.

Current velocity at the study site is 0.10 - 0.2 m / s. Average current velocity is 0.15 m / s. The current velocity of Kelagian Island is still slightly below the ideal current required. Flow has a great influence on the exchange of water masses, aeration, nutrient transport and water mixing, thus affecting the growth of *E.cottonii*. Flows are also very important and play a major role in avoiding the accumulation of sediment (silt) and epiphytic plants attached to the thallus that can block the process of photosynthesis and its growth. A strong current can cause damage to the thallus *E.cottonii*, thalus can be broken and detached. The good flow for seaweed cultivation ranges from 0.2 to 0.4 m / sec (Indriani and Suminarsih, 2005; BSNI, 2010). A slow current can also trigger the attachment of substrate (deposits) on the surface of the thallus and attachment of the epiphytic biota. In addition, the slow currents will inhibit the

circulation of seawater to distribute the much needed nutrients. This is supported by the opinion (Sulistijo, 1996), that in the water the plants are not getting enough nutrients, thus interfering with the process of photosynthesis.

The brightness of the ocean waters is closely related to the extent to which the penetration of sunlight can enter the waters required for photosynthesis. The results of brightness measurements show 100% sunlight, sunlight can penetrate to the bottom of the waters (± 9 m). Intensity and penetration of sunlight greatly affect the process of photosynthesis and growth of seaweed. According to Atmadja et al. (1996a), the role of depth to seaweed growth is related to vertical temperature atratification, light penetration, density, oxygen content and nutrients.

The rate of photosynthesis will increase in line with the increase of light intensity at a certain optimum value (saturation light). The intensity of light is related to the primary productivity of a water.The higher intensity of a light, the higher primary productivity is at a certain limit. The light consumed by its energy will decrease and its penetrating power decreases with increasing depth of water. However, high light intensity will not always increase water productivity. The intensity of light is very high it can inhibit photosynthesis.

The most important and necessary nutrient elements for seaweed growth are nitrate and phosphate. Nitrate concentration analysis was 0.35 mg / L. The high concentration of nitrate is much influenced by the activity in the mainland that produces organic and household waste. Each type of algae, for the purposes of its growth requires a different nitrate content. Seaweeds can grow optimum with nitrate content ranging from 0.9 to 3.5 mg / L (Sulistijo, 1996). WWF (2014) mentions the value of good nitrate ranges from 1-3 ppm. The nitrate content in the study sites was in a good range but still under optimum conditions for *E.cottonii* growth. The content of nitrate that is below the optimum amount is thought to be the cause of the growth of *E.cottonii* is not optimal. According to Effendi (2003) oligotrophic waters have nitrate content between 0 - 5 mg / L, mesotrophic waters have nitrate levels between 1 - 5 mg / L, and eutrophic waters have nitrate levels ranging from 5 to 50 mg / L. The waters of Kelagian Island are oligotrophic.

Phosphate content in the study sites ranged from 0.006 mg / L. The content of phosphate can be a limiting factor both temporally and spatially because of the small phosphate source in the waters. The optimal phosphate range for seaweed growth is 0.051 mg / L - 1.00 mg / L (Indriani and Suminarsih, 2005). WWF (2014) mentioned that the range of good phosphate content is 0.01-0.021 ppm. Simanjuntak (2006) states the relatively fertile waters if the range of nutrients phosphate in normal marine waters is 0.10-1.68 ppm. The phosphate content at the study sites was not in optimum condition to support *E.cottonii* growth. Low phosphate content may be suspected to be the cause of unoptimal *E.cottonii* growth. The base of the sandy reef waters and the study sites are not protected from the waves or open waters (wind wards).

In general, the water parameter values at the study sites are still included in the seaweed cultivation growth range, except for nitrate, phosphate and current velocity under optimum conditions. Measurement of water quality value in this research is done to know the water quality range in the research location. Good water quality is within a tolerable range of water quality and can support the life and growth of seaweed *E.cottonii*.

2.2 Growth rate

2.2.1 Weekly growth rate

The growth rate of seaweed can be seen from the weight gain / weight during the maintenance period (42 days). Initial weight of seaweed at the beginning of maintenance (Week 0), weekly growth rate and *E.cottonii* vertical weighing method (Table 2). While the weekly growth rate is the rate of weight gain *E.cottonii* which is measured every week. The growth of *E.cottonii* in this study is presented in Table 2.

The results of weighing of seaweed at the end of the study showed that the largest *E.cottonii* weight was found at the first depth level (BRL I) with a final weight of 145.33 g while the smallest weight was found in BRL 10 weighing 130.67 g / 6 weeks. The largest average weekly growth was found in BRL 1 weighing 118.08 grams and the lowest weight growth was found in BRL 10 weighing 130.67 g. The results of this study indicate the weight / growth of *E.cottonii* cultivated in the waters of Lampung decreased with increasing water depth.

Table 2 Weekly growth

Depth Level	Average weekly growth measurement results (g / week)							Average
	Weekly 0	Weekly 1	Weekly 2	Weekly 3	Weekly 4	Weekly 5	Weekly 6	
I (0 cm)	75	85.46	99.13	113.07	128.53	136.93	145.33	118.08
II (70 cm)	75	85.33	99.33	111.60	125.40	134.20	143.33	116.53
III (140 cm)	75	85.40	98.27	111.67	124.47	132.80	142.20	115.80
IV (210 cm)	75	86.47	99.13	110.4	122.47	131.60	140.60	115.11
V (280 cm)	75	85	97.87	109	121.40	129.60	139.07	113.66
VI (350 cm)	75	84.93	99.40	110.73	121	129.53	137.93	113.92
VII (420 cm)	75	84.07	96.40	106.20	117.40	126.07	135.40	110.92
VIII (490 cm)	75	82.47	94.93	105.93	116.40	125.40	135.27	110.07
IX (560 cm)	75	82.07	94.67	105.73	116.53	123.73	133.13	109.31
X (630 cm)	75	81.80	92.60	103.60	113.80	122	130.67	107.41

E.cottonii growth rate was highest at week 4 at BRL 1 of 15.47 g and lowest in the first week at BRl 10 with 6.80 g. The growth rate in the first week tends to be slower. This condition is suspected *E.cottonii* still adapt to the environment. The highest average growth rate was found at BRL 1 level with 11.72 g / 6 minggu and the lowest was BRL 10 with 9.28 g / 6 weeks (Table 3). The growth rate of *E.cottonii* decreased with increasing water depth. Different growth rates are influenced by various factors. Temperature, salinity, sunlight, pH, Do are factors that affect growth (Bold and Wynne, 1985; Pratiwi and Ismail, 2004). Seaweed requires sunlight for photosynthesis (Insan et al., 2013). Sunlight will decrease in intensity with increasing depth (level). Lombardi et al. (2006) states that the brightness factor affects growth. Cloudy waters containing sediment will affect growth. Sediments can be attached to the thallus and block the absorption of nutrients and photosynthesis. Depth is the limiting factor of growth rate (Kune, 2007). In addition to the light of other factors affecting growth is the smaller nutrient content of the optimum growth values required (Table 1).

Table 3 Weekly growth rate

Depth Level	Weekly growth rate *E.cottonii* (g /week)							Average
	Weekly 0	Weekly 1	Weekly 2	Weekly 3	Weekly 4	Weekly 5	Weekly 6	
I (0 cm)	75	10.47	13.67	13.93	15.47	8.40	8.40	11.72
II (70cm)	75	10.33	14.00	12.27	13.80	8.80	9.13	11.39
III (140 cm)	75	10.40	12.87	13.40	12.80	8.33	9.40	11.20
IV (210 cm)	75	11.47	12.67	11.27	12.07	9.13	9.00	10.93
V (280 cm)	75	10.00	12.87	11.13	12.40	8.20	9.47	10.68
VI (350 cm)	75	9.93	14.47	11.33	10.27	8.53	8.40	10.49
VII (420 cm)	75	9.07	12.33	9.80	11.20	8.67	9.33	10.07
VIII (490 cm)	75	7.47	12.47	11.00	10.47	9.00	9.87	10.04
IX (560 cm)	75	7.07	12.60	11.07	10.80	7.20	9.40	9.69
X (630 cm)	75	6.80	10.80	11.00	10.20	8.20	8.67	9.28
Total		93	128.73	116.2	119.47	84.47	91.07	
Rerata		9.3	12.87	11.62	11.94	8.44	9.10	

The weekly growth rate shows the first week has the lowest growth rate. In the first week *E.cottonii* is still in the adaptation stage of the environment. Furthermore, the rate of growth will rise until it reaches its peak and will be stationary at weeks 3 and 4, then it will decrease at week 5 to harvest (Table 3). According to Masyahoro and Mappiratu (2012), *E. cottonii* has a growth pattern similar to other macro-algae types. It starts with the exponential phase in the first week to the 3rd week, then the stationary stage at 4th week and begins to decrease at week 5 to harvest. Generally this type of seaweed is ready to be harvested at 42 days after planting, where the content of karageenan seaweed has reached a sufficient level.

2.2.2 Absolute growth rate

The absolute growth of E.cottonii showed BRL 1 had the greatest final weight, while the lowest weight was in BRL 10. The results showed a decrease in the final weight of growth. The deeper the waters (BRL) the weight of the cultivated *E.cottonii* will decrease further. The best growth rate is in BRL 1 with a depth of 0 cm (surface) and a final weight of 145.33 g. While the weight of BRL 10 is the lowest with 130.67 g and is at a depth of 630 cm from the surface of the waters. The results of this study have differences with (Darmawati, 2013) in Laikang Village takalar District, the best growth is at a depth of 50 cm compared to a depth of 20 cm and 100 cm. This difference is thought to be due to differences in research sites and time. In addition, brightness, sunlight intensity and nutrient content also affect. The decreasing weight of *E.cottonii* with increasing depth of waters is thought to be due to limiting factors such as sunlight, nutrients, photosynthesis speed and decreasing temperature. Darmawati (2013) adds lighting (photosynthesis) and nutrient supply also greatly affects *E.cottonii* growth.

The absolute growth rate is the final weight of growth against the initial weight of maintenance. The absolute greatest growth rate is found in BRL 1 weighing 70.33 g and the lowest growth rate of BRL 10 weighing 55.67 g (Table 4). The absolute growth rate is seen decreasing with increasing depth (BRL). The decline in growth rates is thought to be closely related to the decreased intensity of sunlight, temperature and nutrients available. The growth rate graph can be seen in Figure 4.

Table 4 The absolute growth rate of *E.cottonii*

Depth Level (BRL)	Weekly 0	Weekly 6	Absolute growth rate
I	75	145.33	70.33
II	75	143.33	68.33
III	75	142.2	67.2
IV	75	140.6	65.6
V	75	139.07	64.07
VI	75	137.93	62.93
VII	75	135.4	60.4
VIII	75	135.27	60.27
IX	75	133.13	58.13
X	75	130.67	55.67

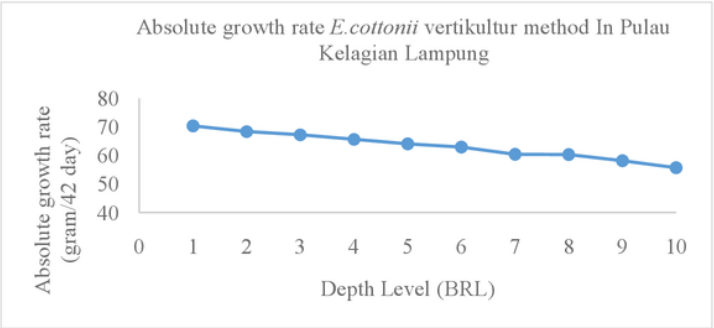

Figure 4 The absolute growth rate of *E.cottonii* vertikultur method

2.2.3 Daily growth rate

The daily growth rate of seaweed cultivation (BDRL) Gracilaria sp at all levels showed poor results (<2% / day). The highest daily growth was BRL 1 level with a growth value of 1.59% / day. While the lowest daily growth rate at BRL 10 level with a value of 1.33% / day (Table 5).

Daily growth in this study was categorized as less optimum, because growth value less than 2% / day. According to Ask and Azanza (2002), Anggadiredja et al. (2006) and Syahlun (2013), the growth rate is good when the daily growth rate is more than 2% / day. According to the result of research (Wisnu Ariyati et al., 2016a), there is difference of daily growth rate of *E.cottonii*, 2.36% in horizontal garden method and 2.03% in vertical planting

method. However, the growth rate in this study has the same growth value as Wijayanto et al. (2014), the growth rate is 1.567% (<2% / day). The similarity of growth rate is assumed to be due to the same research location in the waters of Lampung Bay, so that limiting factors such as sunlight intensity, temperature, salinity, nutrient are relatively no difference. There are several factors that influence the growth rate of seaweed such as sunlight penetration, temperature, salinity and nutrient content. In addition, the presence of predators and pests greatly affect the growth of seaweed. In the study area, there were many baronang and turtle fish. This biota is a natural predator of seaweed. Although seaweed is grown using a net, predation made by turtles and fish beronang can not be avoided. The tip of the thallus that grows out of the net's eye can be easily eaten by fish and turtles. At some point of planting there is a torn bag that has been torn and empty because the seaweed is consumed by predators eaten. This condition is also suspected to be the trigger of low daily growth rate.

Table 5 Daily growth rate

Depth Level (BRL)	Weekly 0	Weekly 6	Daily growth rate
I	75	145.33	1.59
II	75	143.33	1.56
III	75	142.20	1.53
IV	75	140.60	1.50
V	75	139.07	1.48
VI	75	137.93	1.46
VII	75	135.40	1.42
VIII	75	135.27	1.41
IX	75	133.13	1.38
X	75	130.67	1.33

There are several factors that influence the growth rate of seaweed like the depth. The depth of the waters closely related to the penetration of light, the greater the penetration of light in a column of water then most likely the photosynthesis will take place will also be greater. This is in accordance with the opinion of Atmadja et al. (1996b) the role of depth to seaweed growth associated with vertical temperature atratification, light penetration, density, oxygen content and nutrients. Further, it was said by Mohr and Scopfer (1995) in Kune's paper (2007) that the important factor affecting the growth rate of seaweed is the difference in light intensity received by seaweed at different depths. Differences in the intensity of different light will affect the expanse of new cell walls that barely change when the expansion of seaweed's power is inhibited by light.

Water brightness is closely related to the presence of sediment and suspended solids in water. The more sediments and suspended solids in a water column will result in the obstruction of sunlight penetration. The cloudy waters will have low brightness. Low brightness in addition to the effect on light penetration also affects the ability of photosynthesis and growth. This is in accordance with Lombardi et al. (2006) that the brightness affects growth, the sediments attached to the thallus will block the penetration of sunlight required for photosynthesis. While Widowati et al. (2015) mentions that the intensity of light, nutrient supply, depth affect the growth rate of seaweed. In addition, the water depth became one of the limiting factors in the growth of seaweed (Kune, 2007). The more the depth increases the lower the light penetration, and the lower oxygen circulation, in addition to the daily growth rate is also affected by the maintenance time. Another study (Susanto, 2005) mentions currents and waves affect the rate of growth. Weak currents cause the attachment of substrate to seaweed. The substrate attached to the thalus will block out the sunlight and the absorption of nutrients.

In addition to some of the above factors, the origin of the seed and the age of the seedlings also affect the growth of seaweed, the seeds that are used for too long experiencing a slow growth. Seaweed seedlings that are cultivated generally come from seeds from other areas or the rest of the crops are reused. This condition will over time cause the decrease of seaweed production. We recommend the use of seeds derived from new seedlings as a result of tissue culture. Seeds from tissue culture will have a faster growth rate. Seeds that continue to take care of used already saturated and have achieved optimum growth. The daily growth rate of E.cottonii can be seen in Figure 5.

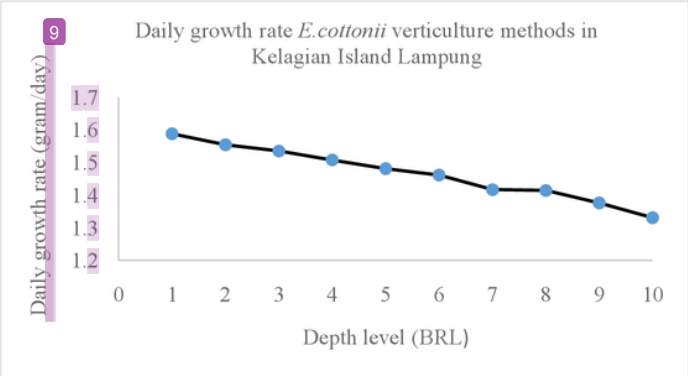

Figure 5 The daily growth rate of *E.cottonii* vertikultur method

2.2.4 Production total rate

The total of seaweed production is total weight of seaweed *E.cottonii* cultivated harvest for 42 days (6 weeks). There are 15 points of planting with each point there are 10 vertical depth level (BRL 1 - BRL 10) with initial weight 75 gram. While the production rate is the difference in a total of production and total of initial weight (Table 6).

Table 6 Total production

Depth level (BRL)	Total weight (W0)	Total final weight	Total growth rate
I	1125	2180	1055
II	1125	2150	1025
III	1125	2133	1008
IV	1125	2109	984
V	1125	2086	961
VI	1125	2069	944
VII	1125	2031	906
VIII	1125	2029	904
IX	1125	1997	872
X	1125	1960	835
	Total production	20744	9494

Production Total of *E.cottonii* cultivated vertically in Kelagian Island waters for 42 days with 10 depth levels (BRL 1 - BRL 10) and 15 planting points was 20744 g (20.744 kg). The highest production is at the depth level of BRL 1 weighing 2180 grams and the lowest on BRL 10 weighing 1960 g. Addition of weight total of *E.cottonii* from all depth level equal to 184,39% from initial weight of planting 11250 g. Land area used 1.28 M2 (1.6 m X 0.8 m). Seaweed production value generated big enough 1.84 times from the initial weight of planting. The production total of vertikultur produced is also quite large, the production value generated 9.51 times the conventional method (raft method, longline and off base) that only utilize surface waters only (only BRL 1). If using conventional method using surface of waters as planting medium (BRL 1) only 1125 g (1.125 kg) will be obtained for wide 1.28 M2 (1.6 m x 0.8 m). Meanwhile, if using vertikultur method by utilizing the depth level will get additional production from BRL 2 - BRl level 10. The production rate is produced up to ten times.

The production obtained is much better than the results of research (Pong-masak, 2010), that the harvest of the vertikultur method is greater than other methods. Results of cultivation of rafts of size 4 x 4 m and a depth of 5 meters obtained 145 kg. While the same raft size and only use the surface only produced 15 kg. The number of stocked seeds can reach 62 kg while the conventional method is only 6.2 kg. However, there is a problem from the results of this study, cultivation can not be done on the type of strong waters. Wavy and wavy waters will cause the breaking of the thallus and the wrapping of the straps. This condition has been successfully overcome in this research that is by using a stronger net and use the weight of the same weight. At the end of the study there was not

a single straps attached. Other research results (Widowati et al., 2015) get better results up to three times, with a depth of 30 cm, 60 cm and 90 cm. While Pongarrang et al. (2013) get triple result with depth 20 cm, 30 cm and 40 cm.

This verticulture method can be recommended for other grass cultivators, in addition to the resulting production value is very large. The method used can also be applied in waters with strong waves and currents. Worries of thalus fractures can be avoided by planting them in the water column and using net pockets. This method can also answer the problem of land limitations. The land is generally in plots and there is often a rarity of land use. In addition, this method can reduce extensive land use and can disrupt the shipping lines.

2.3 Data analysis of seaweed effectiveness

To test the effectiveness of the relative growth rate is done by comparing the growth rate of seaweed in each sample. Before testing the comparison of each sample, the first test of homogeneity and normality test data.

Based on homogeneity test, the result of $H_{count} < H_{table}$, it means reject H1 and receive H0. Data obtained homogeneous. Based on normality test results showed abnormal distributed data, with sig value> 0,05. Further data is processed by using non parametrik test kruskal-wallis. The result of kruskall-wallis test is H value of 21.837 and H value is 23,685. The result shows the value of $H_{count} < H_{table}$. The above data show that H0 is received or no effect of depth level (BRL) on seaweed growth.

Furthermore, there is also a further test of real honest difference (BNJ). Based on the results of further tests there is no significant data based on depth level, BRL 1 - BRL 10. Decision making by looking at significant values and symbols (*) contained in the mean difference. Symbols used in the form of letters a, b, c, and so on. The data above is true does not show significant. Means there is no influence of depth level (BRL 1 - BRL 10) to growth rate of *E.cottonii* in Kelagian Island waters. The results of data analysis showed no effect of depth level on growth rate but average daily growth rate of each depth level <2% / day. According to Ask and Azanza (2002), Anggadiredja et al. (2006) and Syahlun (2013), growth rate> 2% / day is the best growth rate and is recommended for seaweed cultivation. Based on data growth rate and data analysis, seaweed farming in Pulau Kelagian waters allows planting up to level BRL 10 (630 cm from surface).

Unoptimal growth of *E.cottonii* (<2% / day), allegedly the seeds used were not so good and had saturated in the growth process. Seaweed seeds used generally come from the previous harvest and has been done repeatedly. This condition is the cause of saturation of seaweed growth. Good seeds should come from new seeds for example from tissue culture results. In addition there are several environmental factors that are not in the optimum condition for good growth, flow, nitra and phosphate are the three environmental factors that fall below the optimum range for growth. These factors are thought to be the cause of the low value of K.alvarezi's optimal growth.

3 Conclusion

Physics-chemical parameters of seaweed cultivation of *E.cottonii* viticulture method in Kelagian Island is within the optimum range for seaweed cultivation *E.cottonii*, but Nitrate and current contents are under optimum conditions for growth.

Design of vertical cultivation model *E.cottonii* in Kelagian Island using bamboo raft and made up to depth 630 cm. Pocket nets / pocket nets are used to prevent the breaking of thallus by currents and waves also protection from predators.

The largest average weekly growth on BRL 1 with 118.08 g and the smallest on BRL 10 with 107.41 g. The absolute greatest growth rate on BRL 1 weighs 145.33 g and the lowest on BRL 10 with 130.67 g. The highest daily growth on BRL 1 with 1.59% / day and the lowest at BRL 10 with 1.33% / day.

Total production of *E.cottonii* cultivated BRL 1 - BRL 10 by 20744 g, the highest total production at BRL 1 with 2180 g and the lowest BRL 10 by 1960 g. The resulting production rate is 9.51 times that of the conventional method.

Intensification of Seaweed Cultivation Euchema cottonii with Verticulture Method in the Water of Kelagian Island, Lampung Bay

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