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Optimization of Cultivated Seaweed Land *Gracilaria sp* Using *Vertikultur* System

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Abstract The production of *Gracilaria sp* is still not optimal and there are some opportunities left for production improvement by developing methods that use depth level as a planting media. *A vertikultur* method using bag nets is more effective and has higher production levels. This research aims to solve problems in cultivating *Gracilaria sp* seaweed by doing field optimization. Seaweeds were planted as many as 40 points for each 10 levels depth (BRL); 0, 70, 140, 210, 280, 350, 420, 560, and 630 cm from the surface. Environment and seaweed parameters were measured weekly. This research measures daily and weekly growth rate, absolute growth, and the total production. The data were analyzed using *Anota* test and *BNJ further test*. The research result shows that physic-chemistry water parameter is suitable for cultivating *Gracilaria sp*. The lowest weekly growth rate occurred in level BRL 10 in the first week while gaining weight as much as 9.351 gram/week. The highest growth rate occurred in level BRL 4 on the sixth week while gaining weight as much as 32.25 gram/week. The biggest absolute growth occurred in level BRL 4 with 214.87 gram and the lowest occurred in level BRL 10 with 161.45 gram. The biggest absolute growth rate occurred in level BR1 4 while gaining weight as much as 139.87 gram from the original weight and the lowest occurred in level BRL10 with 86.45 gram from the original weight. The best daily growth rate occurred in level BRL 4 with a growth rate of 2.53%/day and the lowest occurred in BRL 10 with 1.84%/day. Total production of *Gracilaria sp* from level BR1 1 – BR1 10 is 74,840 gram. The biggest production was obtained from level BRL 4 with the production of 8595 gram and the lowest in BRL 10 with 6458 gram. According to the anova test result and *beda nyata jujur* (BNJ), it shows that depth level (BR1 1 – BR1 10) gave no influence towards the growth rate of *Gracilaria sp* in the water of Kelagian Island. *The vertikultur* method by making use of depth level is both feasible and profitable for seaweed cultivators with production level ten times bigger.
Keywords *Vertikultur*; Kelagian Island; Seaweed; *Gracilaria sp*

Introduction

Seaweed cultivation is mostly done in water that is relatively calm and closed such as in a bay, behind an island. However, such waters have become too rare. Even if there is one, it usually has been used for cultivation of pearl, fish cages, seaweed, etc. Therefore, it is needed to make a breakthrough by doing an extension and intensification of the land for the cultivation to waters that have strong waves or by maximizing the land available by making use of water depth as media.

Gracilaria sp belongs to red algae group. This kind of algae is on of seaweed that is the most widely cultivated, its production is over 3.8 million ton/year with a value of US$ 1 billion/year (FAO, 2017). China and Indonesia are two biggest *Gracilaria sp* producer countries in the world (FAO, 2017). *Gracilaria sp*'s biomass is used for various purposes for the industrial sector such as industrial jelly (Pereira et al., 2008) and as animal feed (Qi et al., 2010; Johnson et al., 2014). *Gracilaria sp* contributes over 66% from the total production of jelly in the world (Pereira and Yarish, 2008). Until now, there are 185 kinds of *Gracilaria sp* that have been successfully identified (Guiry and Guiry, 2014). Gracilaria has a rapid growth rate (Abreu et al., 2011, Kim and Yarish, 2014; Kim et al., 2015; Wu et al., 2015; Kim et al., 2016; Gorman et al., 2017). This kind of seaweed has a high tolerance towards temperature (eurythermal). The range of temperature that could be tolerated ranged between 0 – 35°C with the optimum temperature for growth ranged between 20 – 28°C (Yokoya et al., 1999; Abreu et al., 2011; Kim et al., 2016). Moreover, *Gracilaria sp* has a wide tolerance towards salinity (euryhaline) ranged between 10 – 40 psu, with the optimum growth 25 – 33 psu (Yokoya et al., 1999; Weinberger et al., 2008; Kim et al., 2016; Gorman et al., 2017).

Gracilaria sp could be cultivated using various method such as longline method in the open sea, seabed, in a pond, and in a cultivation tank (Aslan, 1998; Oliveira et al., 2000; Indriani and Sumiarsih, 2005; Sahoo and Yarish, 2005; Pereira and Yarish, 2008). The success of cultivation depends on some factors which are; season, field's compatibility, planting method, seeds and post-harvest. Some methods were used by seaweed cultivators in Indonesia such as seabed, longline, and ponds (Aslan, 1998; Indriani and Sumiarsih, 2005). The longline method needs a wide field. The use of wide fields costs a lot and the difficulty of maintaining the field could disturb cruise line. The existing method makes use of water surface as a planting media. This condition is very vulnerable to environment changes. Salinity and temperature fluctuation could lead to diseases. Waves and strong currents can cause thallus to break. This condition is different with water column that is relatively stable.

Meanwhile, the use of water column as planting media (*vertikultur*) has not been utilized. *Vertikultur* method is a seaweed planting method with a vertical way by using the depth (water column) as the media. Water depth that has been used could be varied depends on the penetration ability of the sunlight. This method is used while considering optimization, extension, and intensification of the field. The use of the method is expected to increase seaweed's production. According to Aslan (1998), Darmawati (2013), Syahlun (2013), and Wisnu Ariyati et al. (2016), light penetration as the requirement of seaweed production could be obtained not only from one side of water surface but also from every angle of light elevation.

The depth of 30 – 120 cm gives a high response to growth (Safarudin, 2011). Seaweed could grow well because of the incoming sunlight into the water and the movements of the water that bring food substances that are needed by the seaweed. According to Susanto (2005), the growth of seaweed in the water with small waves is relatively smaller. This condition is caused by the attachment of substrate and epiphytic biota that could obstruct the growth (Wijayanto et al., 2014). The growth rate of seaweed in Lampung Bay using raft method is better than seabed and longline method (Pongarrang et al., 2013). On *vertikultur* method, the best planting space is 40cm with the original seed's weight 100 gram. While according to (Herliany et al., 2016), the wider planting spacing will produce gross weight and relative growth that is bigger. Planting spacing 30 cm is better than 20 cm and 25 cm. Farman and Ilham (2015) stated that planting space has an influence on seaweed growth. The best planting spacing is 120 cm than 30 cm, 45 cm, 75 cm, 90 cm, and the original weight 100 gram in *Sargassum sp* cultivation using seabed method. While according to Darmawati (2013), the average daily growth rate in the depth of 50 cm (4.750%), higher than the daily growth rate in the depth of 20 cm (4.427%) and in the depth of 100 cm (3.892%).

Cultivation model that was developed in this research will use the combination of raft cultivation and *vertikultur*. Cultivated Seaweed is not tied but inserted in a kind of net pocket that is specially designed for preventing the break of thallus, fall out, and damaged by the waves, current, and predators. The purpose of this research is to analyze daily growth rate, specific growth rate, absolute growth rate, production and cultivation effectiveness of *Gracilaria sp*.

1 Materials and Methods

1.1 Research method

This research is conducted in Kelagian Island Waters in Lampung Province on September to November 2016.

1.2 Research design

The treatment given in this research is planting seaweed using a combination of depth level (*vertikultur*) as far as 10 levels with the code BRL1 – BRL10 as much as 40 repetition. *Gracilaria sp* seeds were inserted into the net pocket, planting space 70 cm (vertical) and 40 cm (horizontal). *Vertikultur* method using net pocket was designed resistant to the waves and strong current and could optimize the use of the field. The design of *vertikultur* method using net pocket Figure 1.

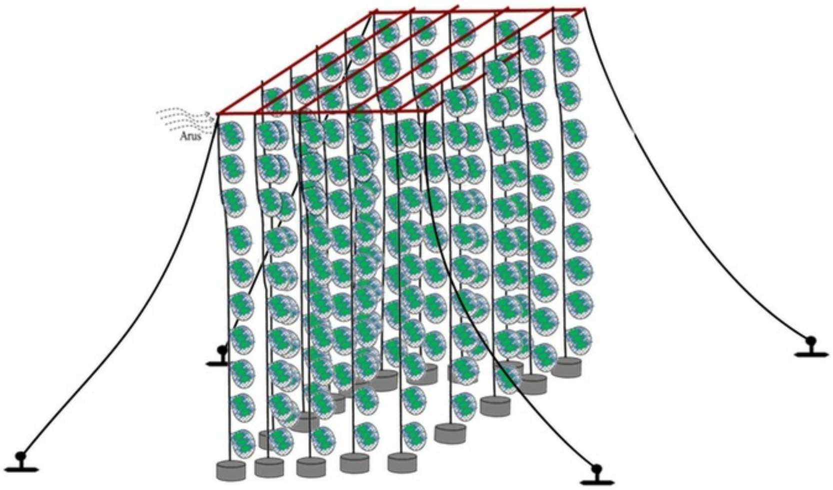

Figure 1 The Design of *Vertikultur* raft of *Gracilaria sp* seaweed

Gracilaria sp seaweed seeds (BRL) that are planted is a young and good thallus. BRL were inserted into a 60 cm net pocket. Time spent for the maintenance is six weeks. The weighing of BRP is done every week.

1.3 Observed variable

Observed data in this research are:

(1) Water quality parameter including water physic parameter which covers: temperature, depth, current speed, brightness, and chemistry parameter which is salinity, nitrate, and phosphate.

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

$$Wa = \frac{Ti}{\sum s}$$

$$WGR = Wa - Wb$$

(3) Absolute Growth Rate (AGR) is final weight (Wt) minus initial weight (Wo), with a formula:

$$AGR = Wt - Wo$$

(4) Daily Growth Rate (DGR) is final weight (Wt) divided by initial weight (Wo) to the power of one/planting time (t) minus one multiplied by 100%, refers to Mtolera et al. (1995), Gerung and Ohno (1997), Aguirre-von-Wobeser et al. (2001), Bulboa et al. (2007), Hayashi et al. (2007), and Hori et al. (2009), with a formula:

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

(5) Total Production Rate is final weight level 'i' (Wl) minus initial weight level 'i' (Wo) plus the amount of cultivation depth level, with a formula:

$$PTR = \sum Wil - \sum Wol + \sum L$$

The data collected were tested *Normality* (Steel and Torrie, 1993). Then, it will be processed using ANOVA test and BNJ further test.

2 Results and Discussion

2.1 Environment parameter

The result of measuring physic and chemistry factors of waters in the research location still decent for seaweed growth. Data is shown in Table 1.

Table 1 Physic and Chemistry Parameter of Waters

Temperature	Salinity	pH	Brightness	Current	Nitrate	Phosphate
29.64	31.57	7.61	100%	0.15	0.35	0.006

Water temperature is around 29-30°C, with average temperature 29.64°C. there is no significant difference in the measurement of waters' temperature during maintenance. The optimum temperature of seaweed growth is 20°C – 28°C (Aslan, 1998; Indriani and Sumiarsih, 2005). *Gracilaria* has a high tolerance towards temperature (0 – 35°C) (Yokoyama, 1999; Raikar et al., 2001; Abreu et al., 2011; Kim et al., 2016). The optimum temperature could improve nutrient absorption process so that it could hasten the growth rate. Seaweed has a varied range of temperature. High-temperature fluctuation could disturb metabolism and growth of *Gracilaria sp*. Excessive temperature fluctuation could be avoided using water mass movement (current).

Water salinity is around 31-32, with average salinity 31.57. the optimum salinity of seaweed growth is 32 ppm (Aslan, 1998; Indriani and Sumiarsih, 2005). *Gracilaria* has salinity tolerance 10 – 40 psu (Gorman and Zucker, 1997; Yokoyama, 1999; Klionsky et al., 2016). Seaweed has a specific range of varied salinity. *Gracilaria sp* is a kind of seaweed that has a wide range (euryhaline). Salinity really affects metabolism and growing process. pH value is around 7.40 – 8.00, with average 7.61. The optimum pH value of seaweed growth is around 7.5 – 8.0 (Aslan, 1998; Indriani and Sumarsih, 2005). The brightness of water is relatively same which is 100%. Sea water brightness is related to sunlight penetration into water area that is needed for photosynthesis process. The result of brightness measurement shows that 100% of sunlight has entered into the seabed. Water brightness decreased on the sixth week. This condition is caused by a small earthquake which makes the water a little murky.

The current in the research are is around 0.1 m/s – 0.2 m/s. The average current is around 0.15 m/s. The current has a big impact in the water mass change, aeration, nutrient transport and water mixing so that it affect the growth. Current also important and can be used to decrease the accumulation of sediment (silt) and epiphytic plants that stick on the *thallus* that can obstruct photosynthesis and growth process. A strong current can cause damage to *thallus* by breaking it and remove it. The current that is good for the cultivated seaweed is around the speed of 0.2 – 0.4 m/s (Indriani and Suminarsih, 2005). In calm water, the vegetation will get less nutrient so that it will disrupt the photosynthesis process.

On the research, location found that the seabed in the form of the sandy reef and the water is in form of windward. The concentration of nitrate and phosphate is around 0.35 mg/l and 0.0060 mg/l. Seaweed can grow to its optimum growth if the nitrate composition is around 0.9 – 3.5 mg/l (Atmadja et al., 1996), while the composition of phosphate is at optimum around 0.051 mg/l – 1.00 mg/l (Indriani and Suminarsih, 2005). The composition of nitrate and phosphate on the research location is at the level that it can sustain the growth of seaweed. Sulistijo (1996) said that the composition of phosphate that good for the seaweed is around 0.02 – 1 mg/l. Generally, those factors on the research location are in the perimeter for *Gracilaria* sp's growth.

2.2 The growth of the seaweed

2.2.1 Weekly growth rate of *Grasilaria* sp seaweed

The growth rate of *Grasilaria* sp is measured once every seven days. Weekly weight gain of the seaweed is recorded in Table 2. The vertikultur method that has been in the application can be seen in Figure 2.

The highest growth rate is dominated by shelf level BRL4 with the depth of maintenance point in 210 cm below the surface, while the lowest growth rate is in shelf level BRL10 with the depth of 630 below the surface (Table 2). The growth in the shelf level BRL4 is affected by several factors such as temperature, salinity, pH, nitrate and phosphate content is in the optimum condition for the metabolism and growth of *Grasilaria* sp.

Table 2 Weekly Growth Rate of *Gracilaria* sp (*WGR*)

Depth Level (BRL)	Weight	Total Growth Rate *Gracilaria* sp (Gram/Weekly Ke-i)					
	0	1	2	3	4	5	6
BRL1	75	93.02	115	131.35	154.87	171.35	183.62
BRL2	75	91.82	116.62	132.8	159.87	177.3	188.3
BRL3	75	87.12	116.57	131.3	147.42	163.8	183.47
BRL4	75	90.32	119.57	137.02	162.32	182.62	214.87
BRL5	75	91.42	116.85	135.35	157.17	187.12	202.32
BRL6	75	89.72	109.55	130.45	153.17	168.8	193.17
BRL7	75	88.27	112.6	132.52	144.77	174.12	187.62
BRL8	75	86.32	104.57	123.02	135.22	155.37	175.72
BRL9	75	86.37	106.12	125.85	136.85	154.37	180.42
BRL10	75	84.35	107.25	121.47	132.05	150.02	161.45

Figure 2 Verticulture Methods

The highest growth rate is in week 6 with 32.25 gram and the lowest is in week 1 with 9.35 gram (Table 3). The relatively slow growth which happens in week 1 is alleged because of the *Grasilaria* sp is still adapting to new environment. While the average growth rate in week 2 with 23.60 gram and the lowest with 13.88 (Week 1). The highest average growth rate occurs in shelf level BRL4 23.31 gram/week and the lowest is in BRL10 with 14.41 gram/week. The difference in growth rate of *Grasilaria* sp is affected by several factors such as temperature, salinity, sunlight, pH, and Do (Bold and Wynne, 1985; Pratiwi and Ismail, 2004). Seaweed needs the sunlight to do photosynthesis (Insan et al., 2013). The intensity of the sunlight will reduce as the depth level increase. Lombardi et al. (2006) stated that the brightness of sunlight can affect the growth of seaweed. A murky water contains sediment that can also affect the growth of seaweed. The sediment may stick to the *thallus* and obstruct the nutrient absorption and photosynthesis process. The depth is a factor that limits the growth rate (Kune, 2007). The intensity of the sunlight will reduce as the depth level increase.

The growth of *Grasilaria* sp is determined by the increase of weight and the number of *thallus* they have. The weight of the cultivation is an increase, increase in weight and the number of the *thallus*. The development of the research is good. The growth can be considered as good if the growth is increased by more than 2%/day. The growth in BRL1 – BRL9 is more than 2%/day only in BRL10 is less than 2%/day. The growth can be considered as good if the daily growth is more than 2% (Ask and Azanza, 2002; Anggadiredja et al., 2006).

According to Erpin et al. (2013) and Widowati et al. (2015b), seaweed has a certain time span to reach their optimum growth. The growth tends to decrease after they reach their optimum growth. On week 6 the weather is not good, is cloudy, is rainy, and there is an earthquake that makes the water murky. Substrates that stick in the *thallus* will obstruct the growth and photosynthesis process. According to Susanto (2005) current and relatively weak wave can cause substrates to stick to the seaweed. The substrates that stick to the *thallus* can obstruct the sunlight and the nutrient absorption. This condition can affect the photosynthesis and metabolism process. With the photosynthesis and metabolism process is obstructed, it will also obstruct the optimum growth as well.

Table 3 Weekly Relative Growth Rate

Depth Level (BRL)	Weight	Growth Rate *Gracilaria* sp (Gram/Week)						
	0	1	2	3	4	5	6	Average
BRL1	75	18.02	21.97	16.35	23.52	16.47	12.27	18.10
BRL2	75	16.82	24.8	16.17	27.07	17.42	11	18.88
BRL3	75	12.12	29.45	14.72	16.12	16.37	19.67	18.07
BRL4	75	15.32	29.25	17.45	25.3	20.3	32.25	23.31
BRL5	75	16.42	25.42	18.5	21.82	29.95	15.2	21.22
BRL6	75	14.72	19.82	20.9	22.72	15.62	24.37	19.69
BRL7	75	13.27	24.32	19.92	12.25	29.35	13.5	18.77
BRL8	75	11.32	18.25	18.45	12.2	20.15	20.35	16.78
BRL9	75	11.37	19.75	19.72	11	17.52	26.05	17.57
BRL10	75	9.35	22.90	14.22	10.58	17.97	11.42	14.41
Average		13.88	23.60	17.64	18.26	20.12	18.61	

2.2.2 Absolute growth of the *Grasilaria* sp seaweed

The absolute growth of *Grasilaria* sp (Absolute Growth Rate) in this research is presented in Table 4. In the end of the research, the highest final weight occurs in the depth level of BRL4 with 214.87 gram. While the lowest is in BRL10 with 161.45 gram (Table 4). There is an increase of 2.15 – 2.86 times of the weight of the seaweed from the beginning of planting. The highest absolute growth rate occurs in level BRL4 with 139.87 gram and the lowest in level BRL10 with 86.45 gram.

Table 4 Absolute Growth Rate (AGR) of *Grasilaria* sp

Depth Level	Weight (*Wo*) (Gram)	Bobot Akhir (*Wt*) (Gram)	Absolute Growth Rate (*AGR*) (Gram)
BRL1	75	183.62	108.62
BRL2	75	188.3	113.3
BRL3	75	183.47	108.47
BRL4	75	214.87	139.87
BRL5	75	202.32	127.32
BRL6	75	193.17	118.17
BRL7	75	187.62	112.62
BRL8	75	175.72	100.72
BRL9	75	180.42	105.42
BRL10	75	161.45	86.45

The highest growth rate in BRL4, allegedly in that depth level, the limiting factors such as nutrient (nitrate-phosphate), salinity, current, pH, temperature, and sunlight are at the optimum level to stimulate the growth rate of *Grasilaria* sp. The decrease in the growth rate because those factors have decreased and it will affect the growth as well.

Absolute growth rate tends to decrease as the depth increase. However, in BRL4 increased growth is occurred (Figure 3). The growth is also quite significant, it even is the highest growth rate of all BRL. This occurs because of several factors such as nutrient, temperature, pH, current, DO, and sunlight in the optimum condition. This research did not measure those factors base on the depth level. Measurement only occurs in BRL1 (surface). The sunlight as one of the instrument for *Gracilaria* sp's growth can penetrate through the water until the seabed. However, with the number of BRL from BRL1 to BRL10, the intensity of the sunlight is decreased as it gets deeper. Sunlight is one of the factors that dominates to affect the growth *Gracilaria* over the other factors.

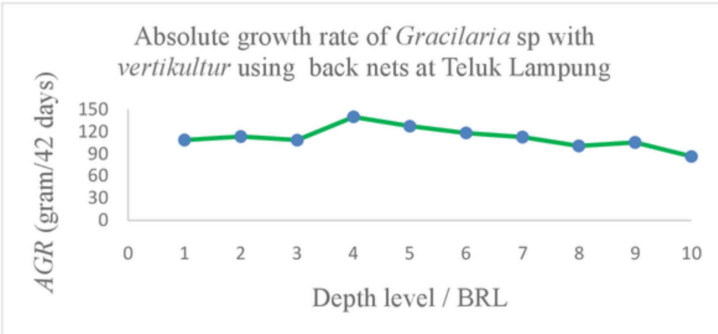

Figure 3 Absolute growth rate of *Gracilaria* sp

The depth level also affecting the growth of the seaweed. A result of the research done by Ponggarrang et al. (2013), in the depth of 40 cm has a better growth rate than in the depth of 20 cm and 30 cm. The intensity of the sunlight mostly affecting the growth of the *Gracilaria* sp. In the depth level that gets less sunlight, the growth will be slow. It is because the photosynthesis process is obstructed (Pratiwi and Ismail, 2004). Seaweed needs sunlight to do photosynthesis. Seaweed can grow in water with a certain depth with the sunlight that reaches the seabed. The result of the growth is affected by cultivation method, the absorption of sunlight for photosynthesis (Insan et al., 2013). The growth of seaweed will be apparent when there is an increasing number of the *thallus* and the increasing weight of the seaweed.

The optimal limit of the depth in *verticultur* method is 5 m (Pong-masak, 2010a). The best growth is in 2 m. in this research, the optimum condition for the growth to BRL10 is 630 cm and the best growth in the depth of 210 cm. The brightness of the water is up to 9 m. However, according to Pong-masak (2010a), it is in the 2 m depth. According to Insan et al. (2013), the best growth is in the depth of 30 cm and 60 cm rather than 90 cm. The growth of *thallus* will be more and fast.

2.2.3 Daily growth rate (DGR)

The daily growth rate of seaweed cultivation (BDRL) *Gracilaria* sp on every level is showing a good result (>2%/day) (Figure 4). The highest growth rate is in level BRL4 with the growth rate of 2.53%/day. While the lowest is in BRL10 with 1.84%/day (Table 5).

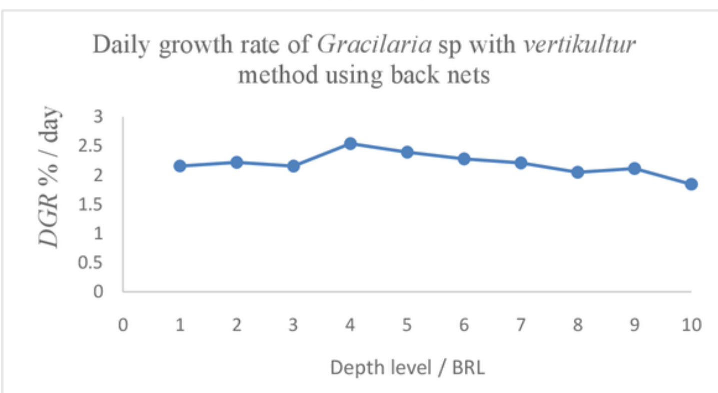

Figure 4 Daily growth rate of *Gracilaria* sp with *vertikultur* method

Daily growth in this research is categorized as good because the growth rate has qualified as good for seaweed cultivation. Growth rate can be considered good if the daily growth rate more than 2%/day (Ask and Azanza, 2002; Anggadiredja et al., 2006; Syahlun, 2013). There are several factors that can affect the growth rate of *Grasilaria* sp. (Lombardi et al., 2006), the brightness of the sunlight, the sediment that sticks to the *thallus* will obstruct the sunlight that is crucial for photosynthesis. Sunlight intensity, nutrient supply, depth also affect the growth of seaweed (Susilowati et al., 2012; Widowati et al., 2015a). The depth is one of the factors in determining the growth of the seaweed (Kune, 2007). With the increase of the depth the lower the sunlight the seaweed can get and the oxygen circulation is low. Also, the daily growth is affected by the maintenance time. Current and wave also affect the growth (Susanto, 2005). They can cause substrates to stick to the seaweed. The substrates that stick to the *thallus* can obstruct the sunlight and the nutrient absorption.

Table 5 *Daily Growth Rate* (DGR)

Depth Level (BRL)	Weight (Wo) (Gram)	Weight (Wt) (Gram)	*Daily Growth Rate* (%/day)
BRL1	75	183.625	2.15
BRL2	75	188.3	2.21
BRL3	75	183.475	2.15
BRL4	75	214.875	2.53
BRL5	75	202.325	2.39
BRL6	75	193.175	2.27
BRL7	75	187.625	2.20
BRL8	75	175.725	2.04
BRL9	75	180.425	2.11
BRL10	75	161.45	1.84

2.2.4 Production total rate (PTR)

Total production of the seaweed is the total weight *Grasilaria* sp seaweed and the harvest of the cultivation in 42 days (6 weeks). There is 40 planting point with 10 level of *vertikultur* depth each (BRL1 – BRL10) with the planting weight of 75 gram. However, the production rate is the difference between total productions and planting weight (Table 6).

Table 6 Production Total Rate (PTR)

Level	Total Weight (Gram)	Total Production (Gram)	Production Total Rate (PTR) (Gram)
BRL1	3000	7345	4345
BRL2	3000	7532	4532
BRL3	3000	7339	4339
BRL4	3000	8595	5595
BRL5	3000	8093	5093
BRL6	3000	7727	4727
BRL7	3000	7505	4505
BRL8	3000	7029	4029
BRL9	3000	7217	4217
BRL10	3000	6458	3458
	Total	74840	44840

Total production that is produced by 10 level of depth with 40 points of planting with the weight of 74,840 gram (74.840 kg) and using 4.8 m^2 (2 m x 2.4 m) land. The highest production is in the level BRL4 with 8,595 gram (8.595 kg) and the lowest is in BRL10 with 6,458 gram (6.458 kg). The production rate is 2.49 times more than the planting weight. Total production of conventional *vertukultur* (horizontal cultivation), whether using seabed, raft or long line method. The result is really good. If it using conventional will only produce 7,345 gram (7.345 kg) using 4.8 m^2 (2 m x 2.4 m). While using *vertikultur* method with its benefit of depth will produce additional production from BRL2 – BRL10. The production rate can reach ten times more.

The production that earned is more than the research (Pong-masak, 2010b) that the harvest of *vertikultur* is five times more than any other method. Widowati et al. (2015a) gets the result three times more with the depth level of 30 cm, 60 cm, and 90 cm. Pongarrang et al. (2013) gets the result three times more with the depth level of 20 cm, 30 cm, and 40 cm. this method can be recommended for other cultivation with the result of bigger production.

This method also can be used in the wavy and strong current water. The concern of the broken *thallus* of *Gracilaria* sp can be avoided by planting it on the water column and using the net pocket.

2.2.5 Data analysis of seaweed growth effectiveness

To test the effectiveness of the relative growth rate can be done by comparing the growth rate of the seaweed of each sample, do the normality test first.

Based on the result of the normality test, Shapiro will show that the data is distributed normally with sig >0.05. After that, the data is processed by using anova test. The result of anova test shown that F count is smaller than the F Table (F count 0.191 < F Table 2.08). The data above show that the H1 is rejected with the consequence of H0 accepted or there is no effect of the depth level (BRL) to the growth of the seaweed.

Next is the advance *beda nyata jujur* (*BNJ*) test. Based on the test, there is no significant data on the depth, BRL1 – BRL10. The result will be drawn by looking at the significance value and symbol (*) in mean difference. The symbol that was used is a, b, c, d and so on. The data did not show any significant whatsoever. It means that the data did not affect the depth level (BRL1 – BRL10) and the growth of the *Gracilaria* sp in Kelagian Island's water. The result did not show that the depth level affects the growth of *Gracilaria* sp which supported by the average growth in each depth level >2%/day. According to Ask and Azanza (2002), Anggadiredja et al. (2006), and Syahlun (2013), the growth that shows >2%/day is the best growth rate and is recommended for seaweed cultivation. Only in BRL10, the growth rate is <2%/day. Based on the data, the growth rate and the data analysis, the *Gracilaria* sp seaweed cultivation in Kelagian Island's water is probable to plant the seaweed up to the level of BRL10 (630 cm below the surface).

3 Conclusions

The conclusions of the research are:

The physics-chemistry parameter of the water of seaweed cultivation *E.cottonii vertikultur* method in Kelagian island still in the optimal limit for the growth of seaweed cultivation of *E.cottonii.*

The lowest weekly growth rate is in BRL10 by the first week with additional weight of 9,351 gram/week. The highest growth rate is in level BRL4 in the sixth week additional weight of 32.25 gram/week.

The highest absolute growth is in level BRL4 with the weight of 214.87 gram and the lowest is in level BRL10 with the weight of 161.45 gram. The highest absolute growth rate is in BRL4 with the additional weight of 139.87 gram from the planting weight and the lowest is in BRL10 with the additional weight of 86.45 gram from the planting weight.

The best daily growth rate (DGR) is in level BRL4 with the growth rate of 2.53%/day and the lowest is in BRL10 with 1.84%/day.

Production total of *Gracilaria* sp from BRL1 – BRL10 by 74,840 gram. The biggest production is gain from BRL4 by 8,595 gram of production and the lowest is in BRL10 by 6,458 gram.

Based on anova test and *beda ntyata jujur* (*BNJ*) show that there is no effect done to the depth level (BRL1 – BRL10) to the growth rate of *Gracilaria* sp in the Kelagian Island's waters.

The *vertikultur* method by using the depth level can be done and profitable for seweed cultivation.

This research sugests that:

For opimization of the land, *Gracilaria* sp cultivation can use vertikultur method with the depth level up to 630 cm (BRL1 – BRL10).

The measurement of the water's parameter preferably done in each depth level to see its effect to the growth.

Optimization of Cultivated Seaweed Land Gracilaria sp Using Vertikultur System

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