Development of seaweed *Kappaphycus alvarezii* cultivation through vertical method in the water of small islands in South Sulawesi, Indonesia

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Abstract. The study aimed to obtain applied technology in overcoming the low productivity and conflict of space utilization through the application of vertical cultivation method on seaweed *Kappaphycus alvarezii*. This study was conducted from March to November 2016 at Saugi Island, Salemo, and Sabutung in Pangkep District and in the water of Sembilan Island in Sinjai District. There were 4 columns used for the study, which showed a significant effect on specific growth rate (SGR) and carrageenan content of the *K. alvarezii*. The best SGR and carrageenan content were produced in the second column. Based on the study of environmental parameters, it showed that the second column had better environmental conditions than in other columns. Further research is required in dry and rainy season for coclude the best cultivation methode of *K. alvarezii*.

Key Words: aquaculture, carrageenan, island productivity, space utilization, method of cultivation.

Introduction. *Kappaphycus alvarezii* is a seaweed with a high economic value, both for consumption and industrial needs in which until now its production has not met the needs. In aquaculture we need innovation in order to meet food demand and other related industries (Tahya 2016), for example seaweed are used as a material to formulate the fish feed (Aslamyah et al 2016). The problem faced by seaweed farmers in small islands is the low production because most of the nutrients in the water column are not utilized. In general, people use longline method that runs horizontally on the water surface. This method utilizes the surface only so that productivity is still low, while the bottom of water column has nutrients that still have the potential to support the growth of seaweed. Cultivation system of seaweed in the environtment is still kept under review to improve the quality and quantity of seaweed produced (Nursidi et al 2017). Longline method also requires a relatively large water surface area that can trigger conflicts of space utilization with fishermen and water transportation service providers. In addition, on the longline method, seaweed gets exposure to the sun that is susceptible to disease.

In principle, the entire water column has nutrients that have the potential to support optimum growth of seaweed. Water derived from deeper waters is rich in nutrients that can be utilized as culture and cultivation media for various types of seaweed (Sahoo & Ohno 2003). Therefore, to overcome the low productivity of cultivation and overcome the problem of space utilization competition in the water, it is necessary to develop applied technology of seaweed cultivation through vertical methods. This method can utilize the entire water column so that most of the nutrients present in the water column can be utilized (Wenno et al 2015).

Along with the development of science and technology in seaweed cultivation, there is a method that is still less applied namely vertical or verticulture method. Vertical method is a method of planting seaweed in a vertical way at a certain depth adjusted to the ability of penetration of sunlight (Widowati et al 2015). The vertical method is carried out by tying the seaweed seeds in a vertical position on the ropes arranged in a row. This method utilizes the water column up to the water's brightness limit. The penetration of sunlight as a condition of seaweed production can be obtained not only from one side of the water surface but also from different angles of light elevation. On the other hand, the nutrient content of the waters is in the optimum water column range (Syahlun et al 2013).

This study aimed to obtain applied technology in overcoming the low productivity of seaweed production and conflict of space utilization through the application of vertical cultivation method of the seaweed *K. alvarezii*.

Material and Method. The research was conducted for 6 months from March to November 2016 in waters of Saugi Island, Salemo and Sabutung of Pangkep District and waters of Sembilan Island of Sinjai District, South Sulawesi Province.

The materials used in this study consisted of PVC pipe 1 and connection pipe L and T as construction material of the container, rope PE10 as construction fastening rope, glue pipe as pipe joint adhesive, rope PE6 as strap rope, rope PE1 as grass rope sea, styrofoam and jerry cans, seeds of seaweed *K. alvarezii*, and nets as a container safety. The research tools consisted of GPS to determine the location coordinate, saws for cutting pipes, drill holes for pipes, underwater cameras for documentation, scales for measuring seaweed weights, and water quality gauges (thermometers, hand-held refractometer (atago), DO meters (YSI 550A), secchi disk, pH meter (HANNA instrument), current meter, and spectrophotometer (UV-VIS)).

Preparation stage. This stage included construction and preparation of seaweed seeds. Construction of containers was made from PVC pipe of 1" with a size of 2 x 1 m (Figure 1). Construction of containers was made from PVC pipe of 1" with a size of 2 x 1 m. To construct 1 container, it took 7 pieces of pipe measuring 1 meter each, 4 pieces of connection L, and 2 pieces of connection T. Connection L in each corner was perforated as a place to insert the rope between columns. Transverse pipes consisting of 3 pipes each in column were perforated with 4 holes as a place to enter the strap. Furthermore, the container was constructed in a rectangular shape by connecting the pipe through a connection pipe and glue pipe to glue the connection. In each construction, it was made 4 straps with space of 25 cm between straps. A total of 24 pieces of media construction were made for 6 point locations where 4 columns were made on each point location. Particularly for the bottom column which near to the sediment of waters, the construction pipe was filled with a cement cast that is meant to be a weight so that the construction was more stable. Seaweed seed used was *K. alvarezii* that obtained from seaweed seed around the research location with an initial weight of approximately 0.5-1.0 grams per bundle.

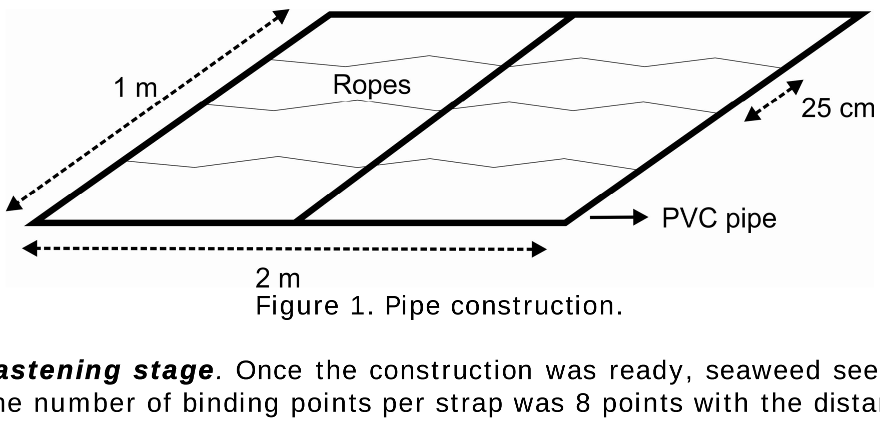


Figure 1. Pipe construction.

Seaweed fastening stage. Once the construction was ready, seaweed seeds were tied to straps. The number of binding points per strap was 8 points with the distance between points of 25 cm. In each binding point, it was tied 2 bunches of seaweed so that the number of bundle in each column was 64 bundles (2 bundles x 8 point x 4 straps). The layout of fastening point of seaweed on the construction of the container can be seen in Figure 2.

Figure 2. Fastening of *Kappaphycus alvarezii*.

Construction stage. After the binding of the seedlings was done, 4 columns (column 1 = 0.5 m, 2 = 1 m, 3 = 1.5 m, 4 = 2 m) were made in the container with spacing between column of 50 cm associated with the strap on each corner. The construction that made from pipe containing cast cement was placed at the bottom (column 4), while the top construction (column 1) was equipped with a float. After all construction was ready, it was taken to cultivation location. Cultivation location consisted of 6 locations, i.e 3 locations in Pangkep District and 3 locations in Sinjai District. Before construction was installed, it was adjusted to the installation coordinate point and measured the appropriate water quality for the cultivation of seaweed *K. alvarezii*.

Observation and measurement stage. Cultivation was conducted for 42 days in a cycle (total 2 cycles) representing the dry season. During the cultivation, control and measurement of water weights and quality were carried out regularly (Figure 3).

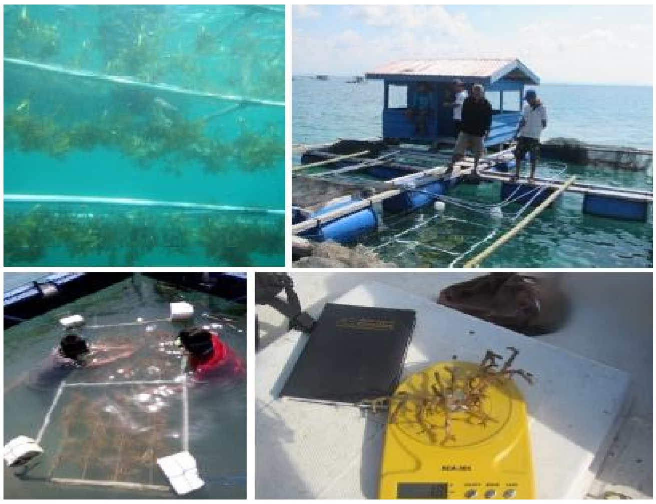


Figure 3. Monitoring of seaweed cultivation.

The data collected in this study consisted of weight data, carrageenan content, and water quality. Techniques of data collection are described as follows:
1. Weights and biomass were measured weekly by sampling each group of different straps and columns. Seaweed samples were taken 1 sample per strap of each column;
2. Carrageenan content was tested for 2 times, in the beginning and in the end of the study. Carrageenan content was analyzed by sampling each of the different straps and columns. The sample tested was taken as many as 1 sample of each strap of each column;
3. Water quality parameter consisted of depth, brightness, flow velocity, temperature, pH, dissolved oxygen, and salinity measured in situ every week, while phosphate and nitrate parameters were measured at the beginning, middle, and end of the research.

The variables of research analyzed are as follow:

1. Specific Growth Rate (SGR) - is calculated by referring the formula of Dawes (1994) as follows:

$$SGR = \frac{LnWt - LnWo}{t} \times 100\%$$

where:

SGR = Specific Growth Rate (%);
Wt = Weight at time of t (gr);
Wo = Initial Weight (gr);
t = Time (day).

2. Carrageenan content (CC) - is calculated by referring to the formula of Munoz (1994) as follows:

$$CC = \frac{Wc}{Wm} \times 100\%$$

where:

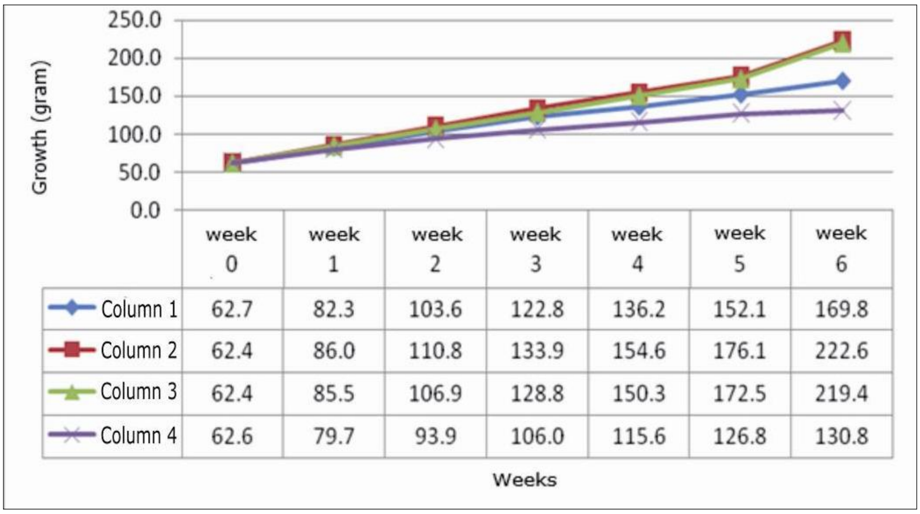
CC = carrageenan content (%);
Wc = Weight of carrageenan extract (gr);
Wm = dry weight of seaweed (gr).

3. Water quality - was measured in the water of the island.

The SGR and CC data were then analyzed using ANOVA, while water quality data were analyzed descriptively.

Results

Specific growth rate (SGR). Average growth rates of seaweed (cycles I and II) cultivated for approximately 6 weeks in each column show varying values. Figure 4 shows that the average initial weight of seaweed in each column was in the range of 62.4-62.7 grams that grew along with cultivation period. The highest final growth result was obtained in second column (222.6 gram), followed by third column (219.4 gram) and first column (169.8 gram), while the lowest growth was obtained in fourth column (130.8 gram). The weight gained in column 1 was 101.9 gram, column 2 was 157.4 gram, column 3 was 153.4 gram and column 4 was 72.2 gram.



	week 0	week 1	week 2	week 3	week 4	week 5	week 6
Column 1	62.7	82.3	103.6	122.8	136.2	152.1	169.8
Column 2	62.4	86.0	110.8	133.9	154.6	176.1	222.6
Column 3	62.4	85.5	106.9	128.8	150.3	172.5	219.4
Column 4	62.6	79.7	93.9	106.0	115.6	126.8	130.8

Figure 4. Growth of seaweed.

The average SGR in each column (Figure 5) shows a value ranging from 1.81 to 3.09% day^{-1}, the SGR between the second and third columns shows a value that is not much different. The highest SGR was obtained in the second column (3.09% day^{-1}), followed by the third column (3.06% day^{-1}), then the first column (2.41% day^{-1}), while the lowest SGR was obtained in the fourth column (1.81% day^{-1}).

The result of variance analysis showed that different columns gave significant effect to seaweed SGR ($p < 0.50$). This is due to different environmental conditions in each water column. It was proved the environmental parameters affected on seaweed growth (Nursidi et al 2017). In each column, there is a difference in the intensity of light that is needed by seaweed as a source of energy for the process of photosynthesis. Solar energy is needed as energy in nutrient uptake (NH_4, NO_3, and PO_4) actively by seaweed for its growth. The occurrence of the different processes of photosynthesis causes different ability of seaweed in each column to obtain nutrients that ultimately affect its growth. Environmental parameters that play an important role in determining the productivity of cultivation are nutrients and light (Harrison & Hurd 2001).

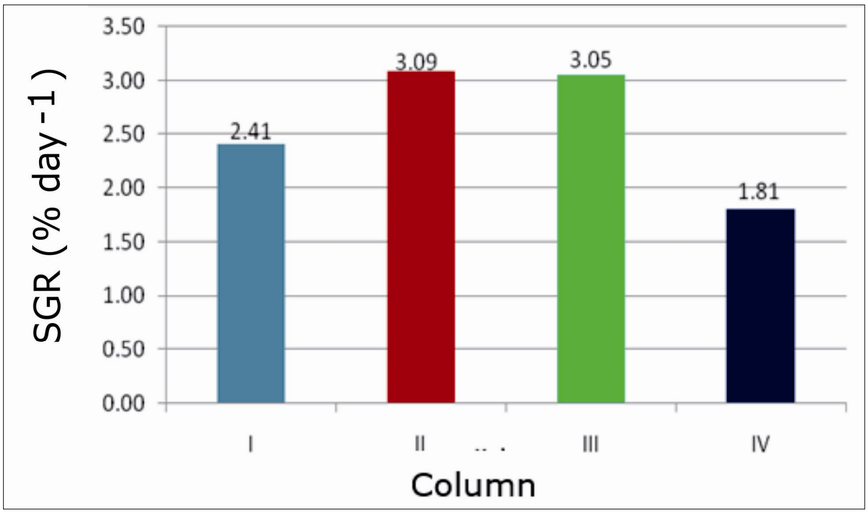


Figure 5. SGR based on the water column.

The movement of water in each column is relatively different which also affects the growth of seaweed due to the different speed of nutrient uptake from water into the thallus due to the influence of water movement. Serdiati & Widiastuti (2010) in Syahlun et al (2013) stated that algae which grown too deeply has a slow movement of water so that the process of entry of nutrients into plant cells and discharge of metabolic residue are obstructed and the thallus is covered by the mud, resulting in the obstruction of the process of photosynthesis, thus growth will be slow.

Further test result using the Tukey test as presented in Table 1 shows that the highest SGR obtained in column 2 was significantly different from the SGR in columns 1 and 4, but not significantly different from column 3, as well as between columns 1 and 4 indicated a significant difference.

Table 1

Tukey test result of seaweed SGR

No.	*Column*	*Average SGR±SE*
1	2	3.8±0.351[a]
2	3	3.04±0.117[a]
3	1	2.40±0.143[b]
4	4	1.81±0.044[c]

Different superscript letters in the same column show significant difference on confidence level of 95%.

The low SGR in column 4 (2 meters depth) is influenced by the low intensity of sunlight penetration compared to the upper column, thus it affects the process of photosynthesis which is the source of energy in nutrient absorption needed for seaweed growth. In addition, the column has relatively low water movement so that the flow of nutrients from water into the thallus tends to be slow which resulted in the low absorption of nutrients for seaweed growth.

The highest growth of seaweed obtained in column 2 (1 meter depth) assumably due to the environment in such column is an optimal condition for seaweed growth. However statistically, the growth of seaweed in column 2 was not significantly different from the growth of seaweed in column 3. Thus, up to column 3 (depth of 1.5 meters), it can still give a good effect for seaweed growth.

Carrageenan content (CC). The average carrageenan content of seaweed (cycles I and II) in each column was in the range of 33.2-35.9% which increases with cultivation duration. The CC showed that the highest CC was obtained in the second column (57.7%), followed by the third column (56.3%) and the first column (53.0%), while the lowest CC was obtained in the fourth column (46.4%). The average increase of carrageenan produced in column 1 was 17.7%, column 2 was 22.1%, column 3 was 20.4% and column 4 was 10.6%.

Variance analysis showed that different columns had significant effect on carrageenan content ($p < 0.50$). This may be caused by different environmental conditions in each water column. West & Miller (2001) stated that the amount of carrageenan content varies according to ecological factors such as light, nutrition, and temperature. Freile-Pelegrin et al (2006) suggested that factors that may affect the quality of carrageenan content are foreign bodies, seasons, light, nutrients, temperature and salinity that can degrade the quality of seaweed. The quantity and quality of carrageenan derived from marine aquaculture varies, not only by varieties, but also the age of the plant, rays, nutrients, temperature and salinity.

Further test of seaweed CC using Tukey test is presented in Table 2.

Table 2

Tukey test result of seaweed CC

No.	*Column*	*Average CC±SE*
1	2	57.7 ± 0.80^{a}
2	3	56.3 ± 1.65^{a}
3	1	53.1 ± 2.06^{a}
4	4	46.5 ± 0.80^{b}

Different superscript letters in the same column show significant difference on confidence level of 95%.

Table 2 showed that the highest carrageenan content obtained in column 2 was significantly different from the carrageenan content of column 4 which has the lowest content of carrageenan, but not significantly different from the columns 1 and 3, as well as between columns 1 and 3 did not show a significant difference but columns 1 and 3 were significantly different from column 4. High level of carrageenan in column 2 (1 meter depth) is due to better environmental conditions in the column, thus the absorption of nutrients runs properly. In addition, it is also suspected that seaweed is protected from excessively high sun exposure which has negative effect of ultra violet light on carrageenan content of seaweed. Statistically, the carrageenan in column 2 is not significantly different from the carrageenan in columns 3 and 1. Thus, up to column 3 (1.5 meters depth) can still produce a good carrageenan for seaweed so that the utilization of water columns for effective seaweed cultivation can be applied.

Water quality. Water quality parameters that influence the growth of seaweed using vertical method are temperature, current velocity, salinity, pH, brightness, and nutrient content (nitrate and phosphate). The results of parameter measurements are presented in Table 3.

Table 3 shows that the relative temperature range differs in each column in which the deeper the water column the lower the temperature. This occurs due to the difference in sunlight exposure received on each column. The temperature during the study was in the range of 28-31°C which is still in the range that can be tolerated by seaweed *K. alvarezii*. Seaweed has a tolerance at a temperature of 24-36^{o}C (Gros 1992 in Patajai

2007). According to Dawes (1981), temperatures affect some physiological functions of seaweed, such as photosynthesis, respiration, metabolism, growth, and reproduction.

Table 3

Data of water quality

Parameter	*Column 1*	*Column 2*	*Column 3*	*Column 4*
Temperature (°C)	30-31	29-30	29-30	28-29
Current velocity (m s^{-1})	0.20-0.40	0.20-0.41	0.22-0.41	0.22-0.37
Salinity (‰)	31-32	31-32	30-32	31-32
pH	7.8-8.1	7.8-8.1	7.7-8.1	7.7-8.0
Phosphate (ppm)	0.11-0.22	0.22-0.30	0.22-0.30	0.25-0.39
Nitrate (ppm)	0.93-1.26	0.97-1.95	0.97-1.95	0.99-1.99

The current velocity during the study was in the range of 0.20-0.41 m s^{-1} which is still within the tolerable range of seaweed *K. alvarezii*. The good current velocity for seaweed cultivation is 0.05-0.20 m s^{-1} (Nursidi et al 2017). Conversely, high currents may possible damage seaweed cultivation, such as the seaweed can be broken, torn, or apart from the substrate.

Salinity is an important parameter in the cultivation of seaweed *K. alvarezii* because this type of seaweed is stenohaline or not resistant to high salinity fluctuations. The salinity of the waters during the study was in the range of 30-32 (‰) which is still within the tolerable range of *K. alvarezii*. Optimum salinity for seaweed cultivation of *Eucheuma* spp. or *K. alvarezii* is at salinity of 33 ppm (Israel et al 2010). Too high or too low salinity will cause disruption to the physiological process of seaweed (Luning 1990).

The pH of the waters during the study was in the range of 7.7-8.1 which is still within the tolerable range of *Kappaphycus alvarezii* (Ilustrisimo et al 2013).

Phosphate level during the study was in the range of 0.11-0.39 ppm which is still in the range that can be tolerated by the seaweed, the optimum phosphate range for seaweed growth being 0.02-1.0 ppm (Guo et al 2015). Phosphate is a key nutrient element in water primary productivity that can increase the activity of plants to perform metabolic processes so as to spur growth, however, a high increase can have an impact on plankton blooming (Indriani & Suminarsih 2003).

Nitrate concentration during the study was in the range 0.93-1.99 ppm which is still in the range that can be tolerated by seaweed (Nuraini 2006; Nursidi et al 2017). Less concentration of nitrate in the waters may lead to inhibition of growth of the seaweed (Nursidi et al 2017).

Conclusions. Seaweed cultivated through vertical methods in the dry season shows growth along with cultivation period. Different columns show a significant effect on Specific Growth Rate (SGR) and carrageenan content. This is due to different environmental conditions in each water column. The best SGR and carrageenan content were produced in second column with better environmental conditions than in other columns. It is necessary to conduct the same research on different seasons and times in the same place or in different places to obtain the best growing season for the growth of seaweed *Kappaphycus alvarezii*.

References

Aslamyah S., Karim Y., Badraeni, Tahya A. M., 2016 Seaweed as a source of carbohydrates in the feed of milk fish (*Chanos chanos* Forsskal). International Journal of PharmTech Research 9(11):64-67.

Dawes C. J., 1981 Marine botany. John Wiley & Sons, Inc., 628 pp.

Freile Pelegrin Y., Robledo D., Azamar J. A., 2006 Carrageenan of *Eucheuma isiforme* (Solieriaceae, Rhodophyta) from Yucatan, Mexico. I. Effect of extraction conditions. Botanica Marina 49:65-71.

Guo H., Yao J., Sun Z., Duan D., 2015 Effects of salinity and nutrients on the growth and chlorophyll fluorescence of *Caulerpa lentillifera*. Chinese Journal of Oceanology and Limnology 33(2):410-418.

Harrison P. J., Hurd C. L., 2001 Nutrient physiology of seaweed: application of concepts to aquaculture. Cahiers de Biologie Marine 42:71-82.

Illustrisimo C. A., Palmitos I. C., Senadan R. D., 2013 Growth performance of *Caulerpa lentifera* (Lato) in lowered seawater pH. Philippine Science High School – Central Visayas Campus Talaytay, Argao, Cebu, Philippines, 43 pp.

Indriani H., Suminarsih E., 2003 [Aquaculture, processing, and marketting of seaweed]. Penebar Swadaya, Jakarta. [in Indonesian]

Israel A., Einav R., Seckbach J. (eds), 2010 Seaweed and their role in globally changing environments. In: Cellular origin, life in extreme habitats and astrobiology. Springer, Dordrecht, 480 pp.

Luning K., 1990 Seaweeds: their environment, biogeography, and ecophysiology. John Wiley & Sons, 527 pp.

Nuraini R. A. T., 2006 [The trial of aquaculture method for *Caulerpa racemosa* as an effort to support sustainability of production]. Jurnal Ilmu Kelautan 11(2):101-105. [in Indonesian]

Nursidi, Ali S. A., Anshary H., Tahya A. M., 2017 Environmental parameters and specific growth of *Kappaphycus alvarezii* in Saugi Island, South Sulawesi Province, Indonesia. AACL Bioflux 10(4):698-702.

Patajai R. S., 2007 [Growth, production, and seaweed *Kappaphycus alvarezii* quality in different aquaculture habitat. Postgraduate Program]. Hasanuddin University, Makassar. [in Indonesian]

Sahoo D., Ohno M., 2003 Culture of *Kappaphycus alvarezii* in deep seawater and nitrogen enriched medium. Bulletin of Marine Sciences and Fisheries, Kochi University 22:89-96.

Syahlun, Rahman A., Ruslaini, 2013 [Growth of seaweed (*Kappaphycus alvarezii*) brown strain using verticulture method]. Jurnal Mina Laut Indonesia 1(1):122-132. [in Indonesian]

Tahya A. M., 2016 [Mandibular organ study and its utilization as molting stimulant of mud crab *Scylla olivacea*]. PhD thesis, Post graduate school, Bogor Agricultural University, Bogor, Indonesia, 76 pp. [in Indonesian]

Wenno P. A., Syamsuddin R., Zainuddin E. N., Ambo-Rappe R., 2015 Cultivation of red seaweed *Kappaphycus alvarezii* (Doty) at different depths in South Sulawesi, Indonesia. AACL Bioflux 8(3):468-473.

West J., Miller K. A., 2001 Agarophytes and carrageenophytes. California's Living Marine Resources: A Status Report. California Department of Fish and Game, Sacramento, CA, 286 pp.

Widowati L. L., Rejeki S., Yuniarti T., Ariyati R. W., 2015 [The efficiency of seaweed *Eucheuma cotonii* production in longline vertical aquaculture method as the alternative in order of water column utilization]. Jurnal Saintek Perikanan 11(1):47-56. [in Indonesian]

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