The Performance of *Kappaphycus alvarezii* seaweed cultivation using net bag and non-bag methods in the waters of Bone Bay, Indonesia

[1,2]Muhammad Rasnijal, [1]Mugi Mulyono, [1]Iin S. Djunaidah

[1] Department of Aquaculture Industry, Faculty of Utilization Fisheries Resources, Jakarta Technical University of Fisheries, Indonesia. [2] Marine and Fisheries Polytechnic of Bone, Aquaculture Technology Study Program, Bone, South Sulawesi, Indonesia. Corresponding author: M. Rasnijal, mrasnijal.bone@gmail.com

Abstract. Cultivation of seaweed by using the long line method is not fully effective because in certain seasons when the weather is extreme, production decreases due to thallus loss during the cultivation. This research aims to determine the performance of *Kappaphycus alvarezii* cultivation that employed net bag and non-bag methods. The experimental design used was completely randomized factorial design, where there were factor A (bag and non-bag methods) and factor B (seedling weight treatments of 15 g, 50 g, 75 g, 100 g, and 125 g). Based on the results of this research, the average daily growth rate (DGR) of *K. alvarezii* with net bag at each different seedling weight treatment was higher than the DGR of *K. alvarezii* with non-bag treatment. The highest DGR was obtained in the A_1B_1 treatment, which was 6.58±0.19%, while the lowest was in the A_2B_5 treatment, namely, 1.59±0.11%. The highest absolute growth, as much as 157.37±2.74 g point^{-1}, was found in treatment A_1B_3, while the lowest was in treatment A_2B_5, only 37.37±1.90 g point^{-1}. Furthermore, the highest wet seaweed production, which was 3.39±0.18 kg m^{-2}, was obtained from the A_1B_5 treatment and the lowest production, which was 1.15±0.14 kg m$^{-2,}$ was found in the A_2B_1 treatment. The results showed that net bag factor, seedling weight factor, and the interaction of the two factors affected the growth of seaweed at 95% confidence level ($\alpha = 0.05$). Therefore, the net bag method was feasible to be applied to improve the performance of seaweed cultivation.

Key Words: daily growth rate, long line, production, thallus.

Introduction. Indonesia, which has an ocean area of 6.4 million km^2, a coastline of 110,000 km, and a tropical climate, is an area that is suitable for the growth of various types of seaweed (Lestari et al 2020). There are around 555 species of seaweed from around 8,642 species in the world that can grow and live well in Indonesian waters (Zainuddin et al 2019). Currently, Indonesia has become one of the main seaweed producers in the world with the wet weight of seaweed production reaching 11.6 million tons in 2016 (FAO 2018). The production was mostly *Kappaphycus alvarezii* (Aslan et al 2020) and *Gracilaria* spp. Indonesia must avail of this geographical condition that is favorable to the development and improvement of seaweed production.

Even though Indonesia is a major global seaweed producer, it turns out that Indonesian seaweed has not been produced optimally. It is indicated by the productivity of Indonesian seaweed farming that is still lower than the productivity of other countries. According to Gultom et al (2019), the productivity of dry seaweed of Indonesia is still very low (1.14 tons km^{-1}), lower than those of several other countries, such as the Solomon Islands (4.55 tons km^{-1}), the Philippines, Tanzania, and India (1.61 tons km^{-1}). The low-performing and underdeveloped management of seaweed farming indicates that although seaweed is a potential commodity, this sector has not yet developed optimally.

One of the factors that are thought to have influenced the low productivity of seaweed cultivation is represented by the cultivation methods and techniques that often cause crop failure. According to Hendri et al (2018); Abdullah et al (2020), one of the factors that influence the growth of seaweed is competition between thalli in obtaining nutrients and the presence of predatory pests that eat seaweed thalli. Generally, *Kappaphycus alvarezii* is cultivated using the long-line method. The use of this method is not yet fully effective because in certain seasons, during extreme weather, the production decreases due to pest attack. The development of a wound on thallus will trigger secondary infection by bacteria and cause thallus to become brittle so that it easily falls off and becomes detached from the ropes (Azizi et al 2018).

Seaweed needs a shelter to protect themselves from pests and to grow properly. The net bag is known to be effective in sheltering seaweed. Mantri et al (2017) stated that the advantage of modifying the net bag method is that seaweed seedlings will not easily disappear, both in sandy and coral-based waters, and seaweed will not be easily eaten by herbivorous fish. The use of the net bag method will reduce the failure of seaweed cultivation caused by extreme weather conditions and predatory pests. This research aims to determine the performance of *K. alvarezii* seaweed cultivation in net-bag and non-bag systems in the waters of Bone Bay.

Material and Method

The research was conducted for 45 days from 12 September to 27 October 2020 in the waters of Bone Bay, Cege Village, Mare District, Bone Regency, South Sulawesi, Indonesia (Figure 1). The research location had water with depths of 220 cm at the highest tide and 30 cm at the lowest tide. The tools used included refractometer, pH meter, thermometer, Secchi disk, digital scale, drifter, stopwatch, tape measure, plastic bottle, scissors, and knife. The materials used were *K. alvarezii* seedlings, monofilament net bags, Polyethylene (PE) rope, plastic bottle buoys, and wooden stakes.

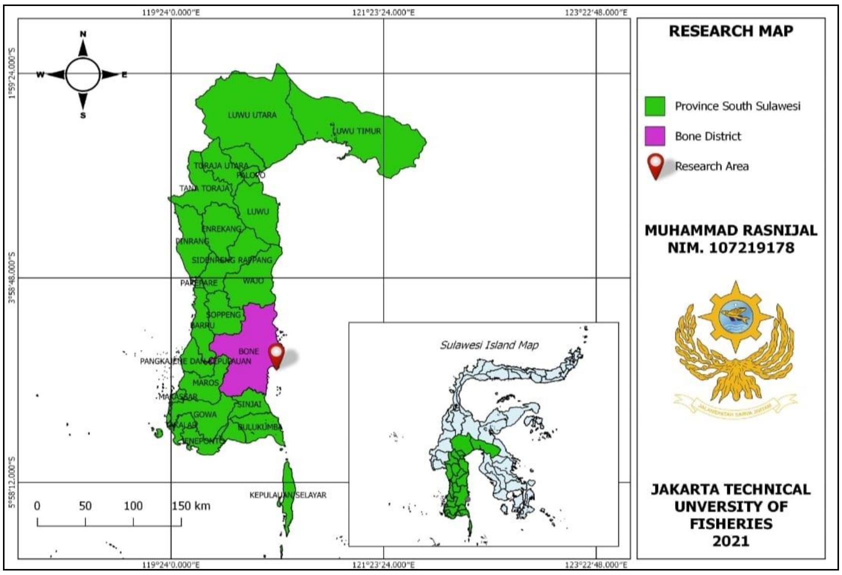

Figure 1. Research location.

The seaweed cultivation method applied was the long-line method that used a 9 mm polyethylene (PE) rope as the main rope, which was made to form a 25×50 m rectangle with wooden stakes and buoys attached to each corner. The number of ropes used was of 30 lines, each of which was 25 m long and stretched on the main rope. The net bag was made of monofilament gillnet number 40 with mesh width size of 3.17 cm. The net size was 23 meshes vertically and 15 meshes horizontally.

Kappaphycus alvarezii seedlings were obtained from seaweed cultivators around the research location. The criteria for seedlings referred to the criteria according to WWF (2014), namely: seedlings that are 25-30 days old, have many branches, have no spots, are not peeled off, are fresh and flexible, are not attacked by disease, are not overgrown with moss or competitor biota, and have many young thalli. Before being utilized, the seaweed seedlings were weighed using a digital scale. Seedlings weighing 15, 50, 75, 100, and 125 g point^{-1}, respectively, were then put into bags for the application of the net bag method (Figure 2). Whereas, for the application of non-bag method, the seedlings were tied directly to the PE rope. The spacing between points was 20 cm, so there were 117 points on each 25-meter-long rope. Each treatment consisted of 3 PE ropes that were randomly installed, so that there were 30 PE ropes installed 1 m apart from each other.

Daily growth rates were sampled every 7 days with random sampling at 10 points on each PE rope and measured. Absolute growth was observed at the end of the seaweed cultivation period by weighing the average weight at each point on the PE rope and subtracting the initial seedling weight from the average weight. Water quality parameters, which consisted of temperature, salinity, pH, water transparency, and water velocity, were measured every two days in the morning. Measurements were made at 4 sampling points. Measurement of nitrate and phosphate levels was conducted every 7 days by taking water sample at the cultivation location, which was then examined in the laboratory of the Research Institute for Brackishwater Aquaculture and Fisheries Extension, Maros District, South Sulawesi.

Figure 2. Seaweed bags.

This research was conducted with an experimental method using completely randomized factorial design, which consisted of 2 factors, namely, Factor A (net bag method and non-net-bag method) and factor B (seedling weights). Factor A consisted of 2 treatments, namely the application of net bag method and non-bag method, while factor B comprised different weights of seaweed seedlings, which consisted of 5 treatments, namely, 15, 50, 75, 100 and 125 g point^{-1}. The treatments that were tested were:

a. Treatment (A_1) net bag, seedling weight of 15 g (B_1)
b. Treatment (A_1) net bag, seedling weight of 50 g (B_2)
c. Treatment (A_1) net bag, seedling weight of 75 g (B_3)
d. Treatment (A_1) net bag, seedling weight of 100 g (B_4)
e. Treatment (A_1) net bag, seedling weight of 125 g (B_5)
f. Treatment (A_2) non-bag, seedling weight of 15 g (B_1)
g. Treatment (A_2) non-bag, seedling weight of 50 g (B_2)
h. Treatment (A_2) non-bag, seedling weight of 75 g (B_3)
i. Treatment (A_2) non-bag, seedling weight of 100 g (B_4)
j. Treatment (A_2) non-bag, seedling weight of 125 g (B_5)

Research parameters. The parameters observed in this study were daily growth rate, absolute growth, seaweed production, and water quality.

Daily growth rate (DGR). Daily growth rate is the percentage ratio between the initial weight of seaweed and the final weight of seaweed each day. The rate is obtained using the formula from Dawes et al (1994) and Periyasamy and Rao (2017) as follows:

$$Daily\ Growth\ Rate = \frac{LnWt - LnWo}{t} \times 100\ \%$$

Where: Wt = Weight of seaweed at time t (g), Wo = Initial fresh weight of seaweed (g), t = Observation period (days).

Absolute growth. Absolute growth is the weight growth (g) of seaweed that is obtained by calculating the difference between final and initial weights. Absolute growth can be calculated using the formula according to Damayanti et al (2019) as follows:

$$W = Wt - Wo$$

Where: W = Absolute growth (g), Wt = Final weight of seaweed (g), Wo = Initial weight of seaweed (g).

Seaweed production. Seaweed production is calculated using the formula from Serdiati and Widiastuti (2010):

$$Pr = \frac{(Wt - Wo)B}{A}$$

Where: Pr is production (kg m^{-2}), Wt is final weight of seaweed (g), Wo is initial weight of seaweed (g), A is length of rope (m), and B is number of planting points.

Water quality. Some of the water quality parameters that were measured are presented in Table 1 below:

Table 1

Water quality parameters

No.	*Parameters*	*Tools used*	*Data collection location*
1	Temperature (°C)	Thermometer	In situ
2	Salinity (ppt)	Refractometer	In situ
3	pH	pH meter	In situ
4	Water transparency (cm)	Secchi disc	In situ
5	Water velocity (cm $second^{-1}$)	Current meter and stopwatch	In situ
6	Nitrate (mg L^{-1})	Spectrophotometer	Laboratory analysis
7	Phospate (mg L^{-1})	Spectrophotometer	Laboratory analysis

Data analysis. The research parameters in the form of daily growth rate, absolute growth, and seaweed production were analyzed by means of the analysis of variance (ANOVA) using SPSS software version 16 with 95% confidence level. Further testing was continued with the Tukey test, while the results of the measurement of water quality parameters are presented descriptively.

Results and Discussion

Daily growth rate (DGR). The average daily growth rates of *Kappaphycus alvarezii* that were obtained in this research are presented in Table 2 below:

Table 2

Daily growth rates (%) of *K. alvarezii*

Factor A (cultivation method)	*Factor B (seedling weight)*				
	15 g (B_1)	*50 g (B_2)*	*75 g (B_3)*	*100 g (B_4)*	*125 g (B_5)*
Net bag (A_1)	$6.58 \pm 0.19^{a*}$ (A_1B_1)	$4.22 \pm 0.16^{b*}$ (A_1B_2)	$3.09 \pm 0.02^{c*}$ (A_1B_3)	$2.67 \pm 0.08^{d*}$ (A_1B_4)	$2.45 \pm 0.06^{d*}$ (A_1B_5)
Non-bag (A_2)	$6.71 \pm 0.11^{a*}$ (A_2B_1)	$3.59 \pm 0.13^{b**}$ (A_2B_2)	$2.55 \pm 0.11^{c**}$ (A_2B_3)	$1.72 \pm 0.03^{d**}$ (A_2B_4)	$1.59 \pm 0.11^{d**}$ (A_2B_5)

Note: (a, b, c, d) Different letters indicate significant horizontal differences ($p<0.05$); (*, **) asterisks indicate significant vertical differences ($p<0.05$).

The results showed that net bag factor, seedling weight factor, and the interaction of the two factors affected the daily growth rate of *K. alvarezii* ($p<0.05$). The daily growth rates of *K. alvarezii* that was cultivated using the net bag method were significantly higher in the treatments of seedling weights of 50, 75, 100, and 125 g point^{-1} compared to those of *K. alvarezii* that was cultivated using non-bag method in general. This is related to the bag that has seaweed protection function. The application of the bag prevents pest predation and protects the thalli from being cut easily by currents. *K. alvarezii* cultivation is inseparable from the intrusion of other organisms, such as pests and marine plants, and waste that causes impaired growth and thus, *K. alvarezii* requires protection to be able to grow properly (Mantri et al 2017; Mako et al 2018). Erbabley et al (2020) stated that the use of net bags in the cultivation of *K. alvarezii* aims to prevent the seaweed from being attacked by pests such as fish and turtles. In addition, if there is a strong current, the fallen thallus will not immediately fall into the water but remain in the bag. The bags also increase the growth of the cultivated *K. alvarezii*.

The daily growth rate between seedling weight treatments in the same *K. alvarezii* cultivation method showed significantly different values. The daily growth rate of *K. alvarezii* using net-bag cultivation method with seedling weight of 15 g point^{-1} (A_1B_1) was 6.58 ± 0.19%, which was significantly higher ($p<0.05$) than the daily growth rate of those using other treatments. Then, the daily growth rate of *K. alvarezii* with a seedling weight of 50 g point^{-1} (A_1B_2) was 4.22 ± 0.16%, or significantly higher, followed by the daily growth rate of seaweed with 75 g point^{-1} (A_1B_3) treatment, which was 3.09 ± 0.02%. Furthermore, the daily growth rate of *K. alvarezii* cultivated using the net bag method with seedling weight of 100 g point^{-1} (A_1B_4) was lower than the daily growth rate of those that were cultivated with other treatments and was not significantly different ($p>0.05$) from the rate of *K. alvarezii* with seedling weight of 125 g point^{-1} (A_1B_5). The daily growth rate of *K. alvarezii* that was cultivated using non-bag method also showed the same results. The highest daily growth rate, which was 6.71 ± 0.11%, was found in the seedling weight treatment of 15 g point^{-1} (A_2B_1), followed by the daily growth rates of 3.59 ± 0.13% in the treatment of seedling weight of 50 g point^{-1} (A_2B_2) and 2.55 ± 0.11% in the treatment of seedling weight of 75 g point^{-1} (A_2B_3). The daily growth rate of *K. alvarezii* with seedling weight treatment of 100 g point^{-1} (A_2B_4) was not significantly different ($p>0.05$) from the daily growth rate of *K. alvarezii* with the seedling weight of 125 g point^{-1} (A_2B_5), but lower than daily growth rate of *K. alvarezii* with other treatments.

The difference in the daily growth rate of *K. alvarezii* with different seedling weights indicates that seedling weight affects the growth of *K. alvarezii*. Tiwa et al (2013) stated that a smaller weight of seedlings will result in faster growth because the available nutrients are well absorbed by the thallus and there is no competition for nutrients.

Research by Sahabati et al (2016) showed that the application of net bags could produce a higher daily growth rate for seaweed with smaller weights of seedling, which were 50 g (3.26%), 100 g (2.97%), and 150 g (2.63%). The same thing was found in seaweeds that were cultivated with initial weights of 50 g, 100 g, and 150 g, respectively, which resulted in a daily growth of 1.73%, 0.78%, and 0.45% during 42 days of cultivation (Ismail et al 2015). In this research, the daily growth rates of *K. alvarezii* with seedling weight treatments of 15, 50, and 75 g point^{-1} were in the optimal range, which was above 3%. Harapan et al (2019) stated that the daily growth rate of seaweed that is considered quite profitable should be more than 3%. On the other hand, the daily growth rates of *K. alvarezii* with seedling weights of 100 and 125 g point^{-1} that was cultivated using both net bag and non-bag methods were below 3%, so it is considered not optimal for application.

Daily growth rate observations carried out weekly on *K. alvarezii* that was cultivated with both net bag (Figure 3) and non-bag (Figure 4) cultivation methods showed significantly different results between treatments ($p<0.05$) at the same time. The daily growth rate of *K. alvarezii* with seedling weight of 15 g point^{-1} was consistently significantly higher than those of *K. alvarezii* with other treatments during the observation period. Furthermore, seedling weight of 50 g point^{-1} showed a significantly higher daily growth rate ($p<0.05$) than seedling weight treatments of 75, 100, and 125 g point^{-1} did. According to observation results at the sixth week, the daily growth rate of seaweed with seedling weight of 75 g point^{-1} was higher than those of seaweed with seedling weights of 100 and 125 g point^{-1}. Meanwhile, the daily growth rate of *K. alvarezii* with seedling weight of 100 g point^{-1} was significantly higher than that of *K. alvarezii* with seedling weight of 125 g point^{-1}. The daily growth rates were significantly different, indicating that seedling weight had no effect on the consistency of seaweed growth if the main factors did not change. The main factors that affected the growth of seaweed were the condition of the thallus and age, water quality, nutrient supply, and presence of predatory pests.

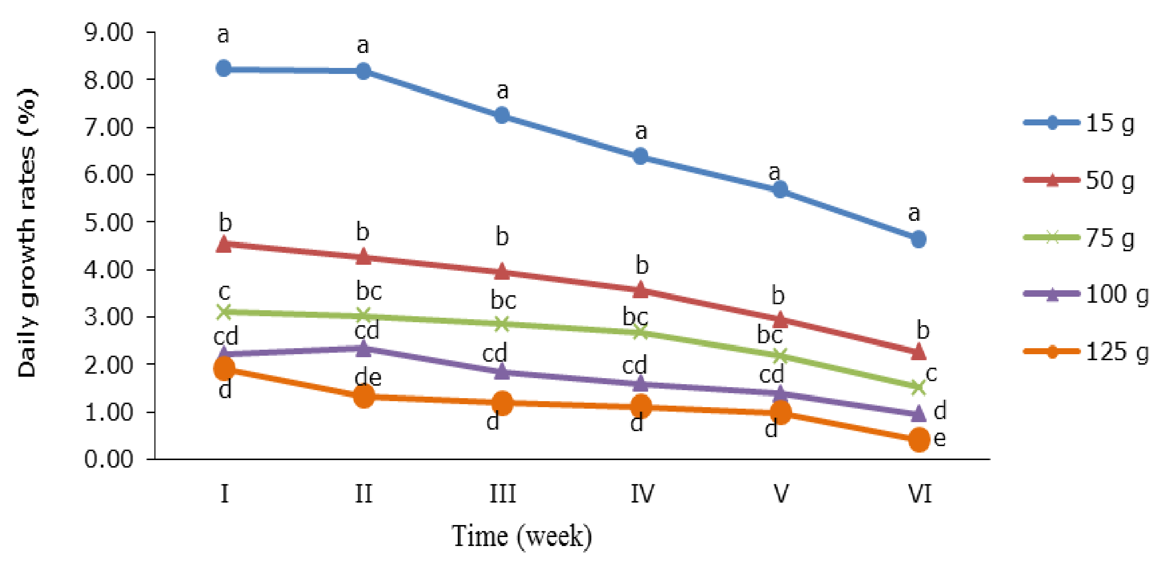

Figure 3. Daily growth rates of *K. alvarezii* that were observed every week in net bag system (different letters indicate significant differences ($p<0.05$) between treatments at the same time).

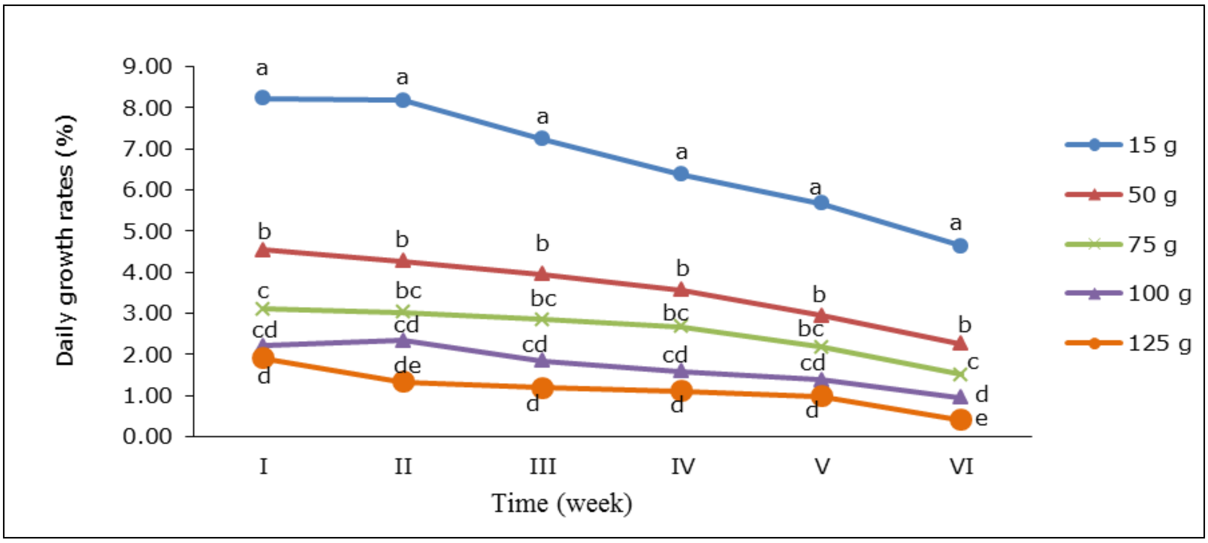

Figure 4. Daily growth rates of *K. alvarezii* that were observed every week in non-bag system (different letters indicate significant differences ($p<0.05$) between treatments at the same time).

The factor that caused the decrease in daily growth rate was the weight gain of seaweed that caused competition for nutrients in the water. This is related to the ability of seaweed to absorb nutrients that declines with age. Harrison and Hurd (2001) stated that seaweed nutritional requirements are influenced by variability, tissue, age, thallus width, and thallus morphology. The young tissue of seaweed absorbs more nutrients than the old tissue does (Wallentinus 1984).

Absolute growth. Absolute growth is the weight growth (g) of seaweed that is obtained by calculating the difference between final and initial weights (Harapan et al 2019). The absolute average growth value of *K. alvarezii* that was cultivated is presented in Table 3 below:

Table 3

Absolute growth (g) of *K. alvarezii*

Factor A (cultivation method)	*Factor B (seedling weight)*				
	15 g (B$_1$)	*50 g (B$_2$)*	*75 g (B$_3$)*	*100 g (B$_4$)*	*125 g (B$_5$)*
Net bag (A$_1$)	113.57 $\pm 3.20^{d*}$ (A$_1$B$_1$)	141.27 $\pm 5.03^{b*}$ (A$_1$B$_2$)	157.37 $\pm 2.74^{a*}$ (A$_1$B$_3$)	131.53 $\pm 7.57^{bc*}$ (A$_1$B$_4$)	126.63 $\pm 6.52^{cd*}$ (A$_1$B$_5$)
Non-bag (A$_2$)	89.73 $\pm 2.71^{a**}$ (A$_2$B$_1$)	78.87 $\pm 1.62^{ab**}$ (A$_2$B$_2$)	65.80 $\pm 5.40^{b**}$ (A$_2$B$_3$)	48.93 $\pm 4.95^{c**}$ (A$_2$B$_4$)	37.37 $\pm 1.90^{c**}$ (A$_2$B$_5$)

Note: (a, b, c, d) Different letters indicate significant horizontal differences ($p<0.05$); (*, **) asterisks indicate significant vertical differences ($p<0.05$).

The results showed that net bag factor, seedling weight factor, and their interaction influenced the absolute growth of *K. alvarezii* ($p<0.05$). The absolute growth of *K. alvarezii* cultivated using the net bag method was significantly higher in all treatments of seedling weights than the absolute growth of *K. alvarezii* in the non-bag cultivation system. The application of net bag on seaweed can prevent broken thalli from falling into the water so that they keep growing in the net bag. Mako et al (2018) stated that the net bag can protect the thalli from disappearing or being cut off. The thalli that are broken from its ties do not immediately fall into the water but remain in the bag so that daily growth rate can be higher. The net bag with a mesh width of 1.25 inch allows proper nutrient exchange while keeping the thallus from breaking and falling into the water.

Absolute growth between seedling weight treatments also showed significantly different values in the same cultivation system ($p<0.05$). In the net bag system, the absolute growth of seedling of 75 g point^{-1} (A_1B_3) was 157.37 ± 2.74 g, which was significantly higher than other treatments. The absolute growth of seedling weighing 15 g point^{-1} (A_1B_1) was 113.57 ± 3.20 g, which was significantly lower than other treatments. This was because the initial weight of the seedlings used in A_1B_1 was lower, so that the absolute growth was also low. Sahabati et al (2016) reported the results of their research that the absolute growth of seaweed was lower for small seedling weights and higher for large seedling weight. The low absolute growth in A_1B_5 was thought to be due to non-optimal growth that was caused by competition among thalli for nutrients. Ismail et al (2015) stated that the initial weight of *K. alvarezii* to be cultivated can influence its growth. A smaller initial weight will lead to faster growth because there is no competition between thalli in obtaining food.

Seaweed production. Production of *K. alvarezii* was observed after 45 days of cultivation on 25 m long PE rope. The results of the observation of *K. alvarezii* production can be seen in Table 4 below:

Table 4

Production (Kg m^{-2}) *K. alvarezii*

Factor A (cultivation method)	*Factor B (seedling weight)*				
	15 g (B_1)	*50 g (B_2)*	*75 g (B_3)*	*100 g (B_4)*	*125 g (B_5)*
Net bag (A_1)	$1,64 \pm 0.08^{c*}$ (A_1B_1)	$2.58 \pm 0.22^{b*}$ (A_1B_2)	$2.99 \pm 0.11^{ab*}$ (A_1B_3)	$3.05 \pm 0.10^{a*}$ (A_1B_4)	$3.39 \pm 0.18^{a*}$ (A_1B_5)
Non-bag (A_2)	$1.15 \pm 0.14^{a**}$ (A_2B_1)	$1.50 \pm 0.11^{a**}$ (A_2B_2)	$1.48 \pm 0.05^{a**}$ (A_2B_3)	$1.44 \pm 0.14^{a**}$ (A_2B_4)	$1.57 \pm 0.26^{a**}$ (A_2B_5)

Note: (a, b, c) Different letters indicate significant horizontal differences ($p<0.05$); (*, **) asterisks indicate significant vertical differences ($p<0.05$).

The results showed that net bag factor, seed weight factor, and their interaction affected the production of *K. alvarezii* ($p<0.05$). Seaweed in the net bag system had significantly higher production for all seedling weight treatments than seaweed in non-bag system did. According to Failu et al (2016), the production of seaweed that was cultivated using net bag method was higher. The bag was able to help the growth of seaweed so that the production was higher. This is in line with data on daily growth rate and absolute growth, which were found to be higher in seaweed that was cultivated by the net bag method. The increase in seaweed production is related to its growth rate, where the higher the growth rate of seaweed is, the higher the production becomes (Failu et al 2016). The low production in non-bag cultivation system is due to the low daily growth rate and absolute growth.

K. alvarezii which was cultivated by the bag method showed significantly different production compared to *K. alvarezii* with other seedling weight treatments ($p<0.05$). Seedling weight treatments of 75 g point^{-1} (A_1B_3), 100 g point^{-1} (A_1B_4), and 125 g point^{-1} (A_1B_5) did not show significant differences, with productions ranging from 2.99 ± 0.11-3.39 ± 0.18 kg m^{-1}. These three treatments were found to be significantly higher than the treatment of 15 g point^{-1} (A_1B_1). The results indicate that different seedling weights affect seaweed production. Greater weight of seedlings results in higher production. On the other hand, by using the non-bag method, the productions of seaweed that was cultivated with different seedling weight treatments did not show significantly different results ($p>0.05$). This was thought to be due to several factors, such as the presence of predatory pests and heavy currents that caused the thalli to break and fall in the water.

Water quality. Seaweed growth is strongly affected by the conditions and quality of the aquatic environment (Glenn & Doty 1990). Therefore, it is necessary to measure water quality to determine the criteria of water quality that can still support the growth of *K. alvarezii*. The water quality parameters are temperature, salinity, pH, water transparency, and water velocity, all of which were measured in situ, while nitrate and phosphate parameters were examined in the laboratory. The results of water quality measurements during the research are presented in Table 5 below:

Table 5

Water quality parameters observed during the research

No.	*Parameter*	*Measurement results*	*Standard according to literature*
1	Temperature (°C)	27.75–29.50	26 – 32 (SNI 2010)
2	Salinity (ppt)	21–29.50	15 – 32 (WWF 2014)
3	pH	7.00–8.62	7.00 –8.5 (WWF 2014)
4	Water transparency (cm)	30–220	> 40 (SNI 2010)
5	Water velocity (cm sec ^{1})	14.73–39.84	15–30 (WWF 2014)
6	Nitrate (mg L^{-1})	0.0427–0.469	1 – 3 (WWF 2014)
7	Phosphate (mg L^{-1})	0.0079–0.0738	0.01 – 0.02 (WWF 2014)

Temperature is one of the factors that influence the physiological processes of seaweed, such as photosynthesis, metabolism, respiration, growth, and reproduction (Gultom et al 2019). According to the observation, the water temperature ranged from 27.75°C-29.50°C, which is the temperature range that still supports the growth of *K. alvarezii*. Meanwhile, according to Setiyanto et al (2008), survival temperature for the growth of *K. alvarezii* ranges from 25°C-30°C.

The water quality parameter that plays a major role in the growth, thallus formation, and morphogenetic development of seaweed is salinity, which is directly related to the osmoregulation system in seaweed cells (Choi et al 2010). Salinity affects the continuity of seaweed metabolism so that the decrease in salinity will affect the growth of *K. alvarezii* (Kasim et al 2019). Salinity measurements during the research showed the results that ranged from 21-29.50 ppt, which is a range that still supports the growth of *K. alvarezii*. This is in line with the opinion of Choi et al (2010), who stated that seaweed will grow slowly if it is at a salinity of less than 15 ppt or more than 35 ppt from the optimum salinity range as a condition for its survival for a certain period.

pH is a measure of hydrogen ions in waters, which is an indicator of the acidity of the water (Yulius et al 2019). Measurement of pH during the research showed pH results that ranged from 7.00–8.62, which is a good range for *K. alvarezii* growth. This is in line with Asni (2015), who stated that seaweed generally grows well in environments with a pH ranging from 6.5-9.5. The pH value at the research location was stable and still in the optimum range so that it did not become a limiting factor for the growth of *K. alvarezii*. According to Risnawati et al (2018), a very extreme pH will be detrimental to the survival of seaweed because it will impair metabolic and respiration processes.

Water transparency is related to the ability of light to pass through the water, which is an important parameter for the photosynthesis process (Yulius et al 2019). Water transparency and sufficient sunlight intensity for the thalli are the main factors in the photosynthesis process that can affect the growth and division of seaweed cells for the seaweed to grow optimally. Measurement of water transparency showed the results that ranged from 30–220 cm, which is included in transparency range that is good for the photosynthesis process. This is consistent with Hayashi et al (2007), who argued that the availability of sunlight intensity will greatly affect the speed at which seaweed meets nutrient needs for their growth and development.

Yulius et al (2019) stated that current is the flowing motion of a mass of water caused by several factors, including wind gusts, changes in sea water density, long wave, and tides. Current plays an important role in the growth of seaweed. It carries nutrients in the water for the metabolism of seaweed. Current velocity is one of the water parameters that can affect the growth rate and production of seaweed (Kasim & Mustafa 2017). The current velocity at the research location ranged from 14.73–39.84 cm sec^{-1}. According to Kasim and Mustafa (2017), the ideal current for the growth of seaweed ranges from 20-30 cm sec^{-1}. Good current velocity can keep seaweed clean from sediment so that all parts of the thallus can function during the photosynthesis process (Kasim et al 2019). Slow currents cause solid particles that stick to the thallus of seaweeds to disrupt the photosynthesis process (Parenrengi et al 2012). Meanwhile, according to Yong et al (2013), the movement of water that transports the sediment at the bottom of the water can cause the surface of the thallus to be covered, which then slows down the growth rate. According to Risnawati et al (2018), currents that are too strong can cause the thallus of seaweed to fall out and to be detached. Therefore, cultivation location for *K. alvarezii* must be protected from intense currents and waves.

The dynamics of current velocity will be influenced by the distance of the seaweed cultivation location from the coastline. The farther the cultivation location is from the sea, the higher the current velocity becomes and vice versa (Asni 2015). It happens because of the influence of the distance traveled to the shoreline that is blocked by seaweeds that are grown over the water surface. The results showed that in the non-bag cultivation system, there were many thalli that were detached from the ropes due to the current velocity that was > 30 cm sec^{-1}. It resulted in lower seaweed production in the non-bag cultivation system and no significant difference between seed weight treatments. In contrast, the highest production was found in seaweeds that were cultivated using net bag method. Therefore, net bag method can be recommended to use. The broken thallus does not immediately fall to the bottom of the water but remains in the bag and continues to grow if the nutrients are sufficient.

Nitrate is the main form of nitrogen in natural waters and is a nutrient for the growth of seaweed. Measurement of nitrate levels showed values ranging from 0.0427–0.2675 mg L^{-1}. This value is still below the optimum nitrate standard. According to Muslimin and Sari (2017), nitrate will be a limiting factor for growth if the concentration is <0.1 mg L^{-1} and >4.5 mg L^{-1}. The low levels of nitrate during the research were probably due to the dry season during observation. This is in accordance with Asni (2015), who stated that nitrate levels are higher in the rainy season than the dry season because during the rainy season, a lot of nitrate enters the water from rainwater. During the rainy season, the amount of water that enters the waters is very large. Low levels of nitrate are believed to affect the growth of cultivated seaweed. This is in accordance with the opinion of Fikri et al (2015), which stated that a nitrate content of 0.9-3.5 mg L-1 is necessary for seaweed to grow optimally.

The results of phosphate level measurement ranged from 0.0079–0.0738 mg L^{-1}. This result is in the category below the optimum standard for seaweed growth. The low levels of phosphate at the fifth week (0.0081 mg L^{-1}) and the sixth week (0.0079 mg L^{-1}) of observation resulted in a decrease in daily growth rate and absolute growth of seaweed. This is in line with the opinion of Zainuddin and Rusdani (2018) that the phosphate concentration for optimum growth for algae ranges from 0.02–1 mg L^{-1}. Pongarrang et al (2013) added that in seawater with a minimum phosphate level of 0.01 mg L^{-1}, the growth rate of aquatic biota will not be hampered, but if the phosphate level drops below the level of 0.01 mg L^{-1}, the cell growth rate will continue to decline.

Conclusions. The results showed that the net bag factor, seedling weight factor, and their interaction influenced the growth performance of *K. alvarezii*. The combination of the two factors showed that the best treatment was A_1B_3 with the use of net bags and a seedling weight of 75 g, which resulted in a daily growth rate of 3.09 ± 0.02%, absolute growth of 157.37 ± 2.74 g, and production of 2.99 ± 0.11 kg.

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Authors:
Muhammad Rasnijal, Jakarta Technical University of Fisheries, Department of Aquaculture Industry, Faculty of Utilization Fisheries Resources, Jakarta, 12520 Pasar Minggu, Indonesia; Marine and Fisheries Polytechnic of Bone, Aquaculture Technology Study Program, Indonesia, South Sulawesi, 92719 Bone, e-mail: mrasnijal.bone@gmail.com
Mugi Mulyono, Jakarta Technical University of Fisheries, Department of Aquaculture Industry, Faculty of Utilization Fisheries Resources, Jakarta, 12520 Pasar Minggu, Indonesia. e-mail: mugimulyono@kkp.go.id
Iin Siti Djunaidah, Jakarta Technical University of Fisheries, Department of Aquaculture Industry, Faculty of Utilization Fisheries Resources, Jakarta, 12520 Pasar Minggu, Indonesia. e-mail: iin.djunaidah@gmail.com

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