Seaweed *Kappaphycus alvarezii* cultivation using longline method in Kastela waters, Ternate Island, Indonesia

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Abstract. The success of seaweed cultivation is highly reliant upon several related factors. This research aimed to study the development of seaweed *Kappaphycus alvarezii* cultivation using the longline method, observe the physico-chemical parameters of the waters, types of pests, growth and production of seaweed *Kappaphycus alvarezii*. This research was conducted in Kastela waters, Ternate Island District, Indonesia, during 45 days, from 23 July to 8 September 2019. The results of the research showed that the physico-chemical parameters of the waters are suitable to support the growth of seaweed *K. alvarezii.* This study also found 2 types of pests in *K. alvarezii* cultivation, namely seeded fish/Baronang fish (*Siganus canaliculatus*) and barnacles (*Balanus* sp.). The highest absolute weight growth obtained was 398 g, and the production of seaweed *K. alvarezii* cultivation reached 16.4623 g m^{-2} within a 45-day maintenance period.
Key Words: growth, thallus, weight.

Introduction. *Kappaphycus alvarezii* is a carrageenan-producing seaweed, a human food source, with important mineral elements such as Ca, K, Mg, Na, Cu, Fe, and Mn (Trono 1992). Carrageenan is used in food products, medicine, cosmetics, textiles, paints, toothpaste, and other products. This shows that the seaweed is an economically valuable commodity that can be traded (Sievanena et al 2005).

Seaweed cultivation has several advantages, like simple technology, affordable capital, profitable business, joint venture, simple maintenance, high market chances, and various processed products (Pongmasak et al 2010). However, the success of seaweed cultivation is highly dependent on several related factors. For the farmers, knowledge about the genus/species of cultivated seaweed is important in optimizing the growth, and minimizing the problems in seaweed cultivation. Factors that determine the success of seaweed cultivation business include the selection of suitable locations, preparation of facilities and infrastructure, selection of qualified seeds, proper planting, determination of appropriate cultivation techniques, proper and routine treatment, accurate pest and disease control and proper harvesting and post-harvest management. The availability of adequate, qualified, and sustainable seeds is another factor determining the success of seaweed cultivation (Radiarta 2013).

This study aimed to determine the development of seaweed *K. alvarezii* cultivation using the longline method, and observe the physico-chemical parameters of the water, pest types, and the growth and production of *K. alvarezii*.

Material and Method

Site location and period.This research was conducted in Kastela waters, Ternate Island District, Ternate City, on the surface of 100 m^2, with a water depth of 90 cm at high tide and 60 cm at low tide. The study was conducted during 45 days, from 23 July to 8 September 2019.

Culture method. The materials used to design a culture container consisted of a main rope with a diameter of 4 mm and a length of 5 m, a stretch rope with a diameter of 6 mm, 5 ropes with a length of 20 m each (the total length of the ropes was 100 m), 4 main buoys, 125 additional buoys (aqua bottles), 2 wooden peg poles, and 4 concrete anchors, each weighting 65 kg.

The seaweed cultivation unit had the size of 5x20 m, containing 5 stretch ropes with a length of 20 m and a distance of 1 m between them. Each of stretch rope contained approximately 78 points of seedling clumps, with a space of 15 cm between them. Healthy seeds were used, presenting several criteria, like lush thallus, many branches, pointed tip, with the age between 25 and 30 days. 2 kg of seeds were obtained from the farmers in Guaimaadu village, Jailolo sub-district, West Halmahera Regency. The binding of seeds was done in a shady beach to make it easier to water the seeds during the binding process. The weight of seeds for each point was approximately 28 g. Planting was done after completing the binding of the seeds to maintain the seaweeds fresh.

Daily maintenance was carried out for achieving the maximum seaweed growth. It consisted in unwrapping stretch ropes wrapped around each other because of currents and waves. Also, mud and dirt attached to the ropes and buoys was removed using a brush. The predators (pests) were monitored to prevent them from disturbing and eating the cultivated seaweeds.

Measurement of physico-chemical parameters of water. The measurement of the physico-chemical parameters of the water was carried out daily by measuring temperature, pH, dissolved oxygen, and salinity. These were measured with the water quality measurement tool Horiba Water Checker. Brightness was measured with a Secchi disk, and the current velocity was measured by timing a float on the water.

Growth observation. The observation of the growth of seaweeds was carried out by weighing the seaweed seeds on each stretch rope. The mass of the seeds weighed was the mass at the first time they were planted and the mass at harvest, at the end of the experiment. The pest observation was conducted by monitoring the cultivation unit on each stretch rope and seaweed thallus.

Production. The production of *K. alvarezii* was calculated based on the difference between the final weight and initial weight divided by the area of seaweed *K. alvarezii* cultivation (100 m^2).

Data analyses. Data analyzed was the absolute weight growth, and the production of *K. alvarezii*. The absolute weight growth was obtained from the difference between the average weight at the end of the research and the initial average weight. The formula used was based on Effendie (1997), as presented below:

$$W = Wt - Wo$$

Where: Wt - final weight; Wo - initial weight. The data about the absolute weight growth and production obtained were analyzed and discussed descriptively.

Results and Discussion

Physical parameters of water

Water depth. Depth is closely related to the sunlight penetration into the waters needed for the growth of seaweeds. It maintains nutrient absorption and prevents the seaweeds from damage by direct exposure to sunlight. This prevents the seaweeds from being dry and can optimize the sunlight acquisition for photosynthesis (Irfan 2014).

The lowest depth in the *K. alvarezii* cultivation was at low tide, 50-100 cm. At high tide, the depth did not exceed 200-300 cm (Irfan 2014). *K. alvarezii* cultivation in Kastela waters had a depth of 90 cm at high tide and 60 cm at low tide. This indicated that the depth of the waters was acceptable for *K. alvarezii* cultivation.

Brightness. The brightness level is related to the turbidity level of the waters, including the quantity of the suspended and dissolved materials in the water, both in the form of mud particles and organic matter. The presence of materials dissolved in water can inhibit the light penetration, interrupting photosynthesis (Irfan 2014). The water had a transparency level from 2 to 5 m (more than 1.5 meters), and it was considered acceptable for the growth of *K. alvarezii* (Anggadiredja et al 2006). The results of brightness measurements ranged from 40.4 cm to 95 cm. According to Sediadi & Budihardjo (2000), brightness values between 1 and 1.5 m are acceptable to support the growth of *K. alvarezii*. Thus, the brightness value obtained was suitable to support the growth of *K. alvarezii.*

Current velocity. The current motion refers to the result of several processes including wind motion above sea level and differences in seawater density caused by solar heating. Currents can also be generated from tidal activities and wave movements, topographical conditions of the water and surrounding islands (Lanuru & Suwarni 2011). Current velocity can determine the growth of seaweed, and play a role in a gas exchange in the water column (Effendi 2000). It can affect nutrient transportation and water stirring, and the growth rate of *K. alvarezii* (Farid 2008). The current velocity values obtained in this study range from 20-40 cm. The current velocity value obtained still supports the growth of seaweed *K. alvarezii*. This is in line with the opinion of Irfan (2014) which states that seaweed *K. alvarezii* grows optimally at a speed of about 20-40 cm s^{-1}.

Temperature. Temperature is an important factor determining the viability and growth of seaweeds (De San 2012). The optimal temperature can increase the nutrient absorption process, accelerating seaweed growth and providing a good functioning of the easiness metabolism (Effendi 2000). Temperature is indirectly related to depth, shallower waters having a faster temperature change, because with the same heat sources, the heating process in shallow waters with less water volume will be faster (Irfan 2014).

The results from the measurement of water temperature showed a temperature range between 28.42 and 29.86°C. Radiarta et al (2004) stated that the water temperature for seaweed cultivation should be from 20 to 28ºC. Water temperature from 28 to 31ºC is considered still acceptable for the cultivation of *K. alvarezii* (Fatmawaty et al 1998). Seaweed grow well in areas with a temperature between 26-33°C (Farid 2008; Tuhumury 2011). Thus, the temperature of Kastela waters used for the cultivation of *K. alvarezii* is still able to support its growth.

Chemical parameters of water

pH. Seaweed *K. alvarezii* needs a typical pH (Munoz et al 2004) where it can commonly grow. The pH values for seaweeds *K. avarezii* range from 6 to 9 (Tuhumury 2011). Different optimal values have been reported because of different values of other parameters. Thus, optimal values can range from 7.5 to 8 (Sediadi & Budihardjo 2000), 7.3-8.2 (Farid 2008), and 7.9-8.3 (Kadi & Atmadja 1998). pH values out of range for seaweed cultivation can hinder the production and growth of seaweed (Tuhumury 2011). Effendi (2000) stated that the pH values of natural seawater range from 7.4 to 8.5. If the pH value is out of this range, the water could be contaminated or experience a high biological activity. The results of pH measurements in this study showed pH values from 7.5 to 8.3, indicating that the pH was still suitable for the cultivation of *K. alvarezii*.

Dissolved oxygen. Dissolved oxygen content is related to water depth, decreasing with increasing depth (Irfan 2014). Farnani et al (2013) stated that dissolved oxygen content for seaweed *K. alvarezii* cultivation should be between 3-8 ppm. In this study, dissolved oxygen was between 3.3 and 5.3 ppm. Thus, the value of dissolved oxygen content obtained was considered acceptable for the cultivation of *K. alvarezii.*

Salinity. Salinity is an important factor that determines the growth and development of seaweed (Arisandi et al 2011; Irfan 2014). It is directly related to the osmoregulation occurring in cells. The different concentrations of fluid inside and outside the cells stimulate the Golgi apparatus to continue reaching for equilibrium until becoming isotonic. This brings an impact on the greater energy utilization; therefore, it affects the growth and development of seaweeds, hindering it.

The salinity needed by *K. alvarezii* is between 18 and 35‰ (Dawes 1985); 28-35‰ (DKP 2009), 33-35‰ (Arfah & Papalia 2008). The difference in salinity values is due to differences in the location of seaweed *K. alvarezii* cultivation and different values for other parameters. In this study, the values ranged from 31.6 to 32.9‰. Thus, the salinity value obtained was still acceptable for *K. alvarezii* cultivation.

Pest identification. The research also identified 2 types of pests in the cultivation of *K. alvarezii*, the juveniles of Baronang fish (*Siganus* spp.), especially *Siganus canaliculatus*, and barnacles (*Ballanus* sp.). Baronang fish frequently approached and ate the seaweed thallus planted around the cultivation site, and it later on caused some of the seaweed thallus to peel, turn white, and break off its tips. Meanwhile, barnacles often attached to the stretch ropes, main ropes, and seaweed thallus. The larger barnacles attached to the older thallus, while the smaller ones attached to the young thallus. During observations, it was found that the attachment of barnacles was commonly followed by the growth of moss around the thallus, while the thallus gradually turned white. Overall, the number of pests and symptoms of damage in seaweed cultivated by the longline method can be seen in Table 1.

Table 1

Pests and damage in seaweed *Kappaphycus alvarezii* cultivated using the longline method

No	*Species*	*Number of pests*	*Damage*
1	Beronang fish (*Siganus* spp.)	5	Thallus peeled off and turned white; broken tip. Not all thallus were eaten. The seaweed did not experience decomposition.
2	Barnacles (*Ballanus* sp.)	8	Thallus with barnacles attached gradually turned white.

Growth. Table 2 shows the results of observations on absolute weight growth in seaweed *K. alvarezii* on each stretch rope.

Table 2

The average absolute weight growth (g) on each stretch rope

Stretch rope	*Average absolute weight growth (g)*
1	375.23
2	398
3	345.33
4	233.97
5	293.7

As presented in Table 2, the results showed that the average absolute weight growth of *K. alvarezii* varied on each stretch rope. On rope 1, the average absolute weight growth reached 375.23 g. Meanwhile, averages of absolute weight growth on stretch ropes 2, 3, 4 and 5 were 398 g, 345.33 g, 233.97 g, and 293.7 g, respectively. The total average of absolute weight growth on each of the stretch ropes is 1646.23 g.

At the beginning of planting, the seaweed seeds detached from the ropes were replaced. Similarly, any detached ropes were replaced with new ones. This, however, just occurred in the first week. Furthermore, the seeds and point ropes that were detached were no longer replaced considering the relatively limited number of seed stocks available. From the maintenance period to harvest time, seaweeds were harvested based on the condition of the planting point as well as on the number of seeds on each stretch rope. This made the number of planting points to vary at harvest time on each rope and the amount of weight in each planting point on each rope was different.

The results of observation showed a difference in the values of absolute weight growth due to the differences in the number of planting points, where some seeds at each planting point on each rope were detached due to the strong currents during planting or maintenance until the harvest time. The existing data showed that the highest absolute weight growth was found on rope 2, amounting to 398 g.

In general, there are many factors affecting the growth of seaweeds including the genus/strain of seaweed, thallus, age of seeds, and physico-chemical environmental factors, among others (Mamang 2008). Anggadiredja et al (2006) stated that seaweed *K. alvarezii* has fast growth and a short maintenance period, being harvested within 30-45 days. Its cultivation technology is very simple. Therefore, seaweed *K. alvarezii* is commercial seaweed with high economic value.

Thallus used for seaweed cultivation was young. The part of thallus selected was the plant tip consisting of cells and young tissues that can provide normal growth (Irfan 2015). Meanwhile, the age of the seeds used ranged between 25 and 30 days. These seeds were able to provide a good growth (Zatnika 2009). Anggadiredja et al (2006) stated that seaweed seeds for planting must be selected with several criteria: having lust branch thallus with pointed tip, being in healthy condition without any spots, cuts or peeling caused by the ice-ice disease or being exposed to contaminants, such as oil. In addition, the seeds of *K. alvarezii* must be fresh, with bright color (bright brown and bright green).

Production. The analysis results showed that the average production on each of the 5 ropes was 16.46 g m^{-2} and the total production was 100.062 kg. Compared to the number of seeds planted, 2 kg, the yield showed that the production achieved was very high within a 45-day maintenance period.

Conclusions. From the results of this research, it can be concluded that the physico-chemical parameters of the water support the growth of seaweed *K. alvarezii*. There were 2 types of pests in the cultivation of *K. alvarezii*: juveniles Baronang fish (*Siganus canaliculatus*) and barnacles (*Balanus* sp.). The highest absolute weight growth was obtained on rope 2 (398 g). The total production of seaweed *K. alvarezii* amounted to 16.4623 g m^{-2} within a 45-day maintenance period.

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