Application of mesh bags and non-mesh bags using the off-bottom method in seaweed cultivation of *Halymenia* sp.

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Abstract. *Halymenia* sp. seaweed offers a great deal of promise for development in aquaculture because of its quick growth and lack of preference by seaweed predators. These characteristics attract farmers and businesspeople. The purpose of this study was to ascertain the growth of *Halymenia* sp. using off-bottom bagged and non-mesh bag methods. This study was carried out in the coastal waters of Kastela, Ternate City, Ternate Island District, Indonesia. A tube-shaped seaweed bag with a 25 cm diameter and 50 cm height was employed as the research container instead of a net bag, for the non-net bag method. The growth of seaweed grown by bag and non-mesh bag methods was compared. Both absolute and relative weight increase data were examined. The findings demonstrate that the cultivation of *Halymenia* sp. using the net bag and non-mesh bag methods resulted in noticeably different effects on absolute weight growth and relative growth. The absolute weight growth and relative growth of *Halymenia* sp. were better when using the net bag method.

Key Words: absolute weight growth, coastal waters, Kastela, relative growth, Ternate city.

Introduction. A seaweed genus that belongs to the red algae family and generates carrageenan is *Halymenia* (Fadilah & Pratiwi 2020). Carrageenan serves as a stabilizer, thickening, gelling agent, and emulsifier, and it is important to the food, pharmaceutical, and cosmetic sectors. *Halymenia* offers a great deal of promise for development in aquaculture because of its quick growth and lack of preference by seaweed predators. These characteristics attract farmers and businesspeople (Robledo & Freile-Pelegrin 2010; Cahyadi 2013).

The proper method must be used in conjunction with the development of cultivation technology for the seaweed to be successfully cultivated, as doing so is predicted to boost the production and productivity of the seaweed cultivation industry as a whole. The *Halymenia* cultivation technology has not been developed significantly, and more studies are required to learn more about suitable cultivation techniques. The implementation of the bagged and non-mesh bag methods is anticipated to raise seaweed farming production. Additionally, it is anticipated that employing these methods will be an alternative to using the off-bottom method, giving producers another option in sustainable farming of this seaweed.

Although Ternate City in North Maluku Province, Indonesia, specifically, has great promise for *Halymenia*, growth through its cultivation has not gone well. This is because there is a lack of studies to support this genus and method of cultivation. Therefore, the aim of this paper is to provide some information about cultivation development technology using mesh and non-mesh bags.

Material and Method

Study area. This study was carried out in the coastal waters of Kastela, Ternate Island District, Indonesia. The process of growing *Halymenia* seaweed took 45 days to complete, from June to August 2022. The research implementation time started with the preparation of the research tools and materials.

Research vessel preparation. There was no mesh-bag utilized in the research vessels, which were tube-shaped seaweed containers with 25 cm diameter and 50 cm height. The initial weight of *Halymenia* was 50 g per clump. 20 clumps were used in the study. Each clump was fastened to the bottom of the bag, facing up.

For each method (non-mesh bags and mesh bags), a rectangular structure with a mesh size of 3.8 cm composed of polyethylene rope and supported with concrete anchors supports the *Halymenia* culture. There were five stretch ropes in the cultivation structure. Stretch ropes were positioned 25 cm apart from one another.

Placement of cultivation containers. At a water depth of 1 m, the structures were placed for the bag and non-net bag methods for growing *Halymenia*. In the cultivation construction, there were six rope stretches in total, for 2 treatments repeated 3 times (6 experimental units): A - the mesh bag method, B - the non-mesh bag method.

Observations. The thallus weight increase was noted for each container. The aquatic environmental parameters were determined every week. Temperature, pH, salinity, dissolved oxygen were measured with a Horiba water checker. A float and stopwatch were used to determine the current speed. Each of these parameters was measured once a week.

Data analysis. Absolute weight growth was determined using the following formula (Amin et al 2005):

$$W = Wt - Wo$$

Where: W - absolute weight growth (g); Wt - final weight (g); Wo - initial weight (g).

The relative growth rate was determined with the following formula (Dharmawaty et al 2016):

$$LPN = [Ln(Wt - Wo)]/t \times 100$$

Where: LPN - growth rate (%); Wo - wet weight of *Halymenia* at the beginning of the study (g); Wt - wet weight of *Halymenia* at the end of the study (g); t - maintenance time (60 days).

The study used a completely randomized design (CRD). The analysis of variance (ANOVA) was used in data analysis, and if the treatments administered had a different impact, the Least Significant Difference test (LSD) was further employed (Steel & Torrie 1993).

Results and Discussion

Absolute weight growth. Table 1 displays the findings of the analysis of the average absolute weight increase of the seaweed *Halymenia* sp. Each treatment had a different effect on the increase in the absolute weight of *Halymenia*, with treatment A having an increase on average of 24.66 g and treatment B of 14.66 g per clump (Table 1). Treatment A has a larger average absolute weight growth value than treatment B. The results of the variance analysis are displayed in Table 2.

Table 1

Absolute weight increase (g) of seaweed *Halymenia* in each treatment

Repetition	*Treatment*	
	A	*B*
1	24	14
2	25	15
3	25	15
Total	74	44
Average ±SD	24.66±0.57	14.66±0.57

Table 2

Results of absolute weight growth of seaweed *Halymenia*

Source of diversity	*Degrees of freedom*	*Sum of squares*	*Middle square*	*F count*	*F table*	
					0.05	*0.01*
Treatment	1	150.006	150.006	449.793^{**}	7.71	21.2
Error	4	1.334	0.3335			
Total	5					

Note: ** - very significant difference.

The analysis of variance results in Table 2 demonstrate that the calculated F value (449.793) is higher than the F table values for 0.05 and 0.01, indicating that the effect on the absolute weight growth of *Halymenia* is statistically very different. The LSD test in Table 3 revealed that how each treatment's impact varied.

Table 3

Results of the LSD test regarding the effect of each treatment on the growth of absolute weight of *Halymenia*

Treatment	*Average*	*Difference*		*LSD*	
				0.05	*0.01*
				1.307	*2.168*
A	24.66	-			
B	14.66	10**	-		

Note: ** - very significant differences.

According to the LSD test results, treatment A produced very significantly higher values than treatment B. Compared to the non-mesh bag approach, *Halymenia* seedlings in treatment A were effectively protected at the time of planting, which contributed to the high absolute weight growth. The quality of the water surrounding the culture site, particularly the temperature, salinity, and current speed, also contributed to the high absolute weight growth.

The size of the mesh bag was big, more than 1 cm. This is another feature that contributed to the high absolute weight growth, allowing nutrients to flow easily into and out of the mesh bag and supporting plant growth (Arfah & Papalia 2008; Muslimin & Sari 2017). *Halymenia* is supported by the substrate, which is its primary habitat. The placement of the mesh bag on the bottom allows the growth of the seaweed. According to Hernandez-Kantun et al (2012) and Erbabley et al (2020), one benefit of the mesh bag approach is that it can shield seaweed seedlings from strong currents, allowing them to survive and supporting growth.

Compared to the mesh bag approach, the non-mesh bag method produces a slower growth. When *Halymenia* is planted, the extreme weather conditions make it difficult for the seaweed to adapt. According to Erbabley et al (2020), the non-mesh bag approach can cause a drop in production due to fish predation on seaweed, moss attachment to the thallus, and ice-ice disease. It can also lead to crop failure. he non-mesh bag method is actually simple to use and does not have high costs.

Relative growth. The results of the relative growth analysis of *Halymenia* seaweed are presented in Table 4.

Table 4

Average relative growth (% per day) of seaweed *Halymenia* in each treatment

Repetition	*Treatment*	
	A	*B*
1	0.871	0.548
2	0.9	0.582
3	0.9	0.582
Total	2.671	1.712
Average	0.89±0.01	0.57±0.02

Halymenia seaweed has a variable relative growth value. The average relative growth value for treatment A was 0.89% per day, while for treatment B it was 0.57% per day. Table 5 presents the effects of the treatments on the relative growth rate of the seaweed.

Table 5

Results of the analysis of the relative growth variety of seaweed *Halymenia*

Source of diversity	*Degrees of freedom*	*Sum of squares*	*Middle square*	*F count*	*F table*	
					0.05	*0.01*
Treatment	1	0.1533	0.1533	471.692**	7.71	21.20
Error	4	0.0013	0.000325			
Total	5					

Note: ** - very significant differences.

According to Table 5, the calculated F value (471.692) is greater than both values for 0.05 and 0.01, indicating that the influence on *Halymenia*'s relative growth is significantly different. The LSD test in Table 6 confirms each treatment's effect.

Table 6

LSD test results for the relative weight growth of *Halymenia* according to treatment

Treatment	*Average*	*Difference*		*LSD Test*	
				0.05	*0.01*
				0.04	*0.067*
A	0.89	-			
B	0.57	0.32**	-		

Note: ** - very significantly different.

The LSD test results revealed that treatment A produced a significantly higher relative weight growth than treatment B. The mesh bag method produced the greatest average relative growth value of 0.89% per day.

Water quality. Table 7 contains the findings from the study's water quality parameter observations.

Table 7

Water quality during research

Parameters	*Range*
Temperature (°C)	27-30
Current speed (cm/sec)	20-40
pH	7.3-7.6
Salinity (‰)	29-32
Dissolved oxygen (ppm)	3.5-3.8

Temperature. The physiological processes of seaweed, including photosynthesis, respiration, growth, and reproduction, are influenced by temperature (Dawes 1995). The recommended water temperature range for seaweed management is 20-32°C, with other authors suggesting a range between 27-30°C (Widyartini & Insan 2007; Farid 2008). A rise in temperature brings on symptoms including paleness, yellowing, and overall unhealthy algae (Effendi 2000; Dawes 1995). The low growth of seaweed will be produced by a drop in water temperature to 20^{o}C (Qian et al 1996). 26-32°C is the ideal range for *Halymenia* cultivation (Fadilah & Pratiwi 2020). *Halymenia* could survive and grow at the study site at the water temperature that was determined during the research.

Sea current. Enough water movement will promote ventilation, reduce salinity and temperature swings, and prevent pollutants from building up in the thallus (Thana et al 1993). The ideal current velocity for growing seaweed is between 20 and 40 cm s^{-1}. Currents over 40 cm s^{-1} may break seaweed branches and harm cultivation containers (Ariyati et al 2007). The current velocity in this study ranged from 25 to 40 cm s^{-1}, sustaining the growth of *Halymenia*.

The pH. The pH is a limiting factor for plant growth. Although the pH should be generally steady, industrial waste, temperature, and photosynthetic activity can all have an impact on pH. In general, the ideal pH range for growing seaweed is 7.3 to 8.2 (Pongmasak & Sarira 2015). *Halymenia* cultivation requires a pH between 7.8 and 8.4 (Fadilah & Pratiwi 2020). The pH value obtained in this study supported the growth and survival of cultivated of seaweed *Halymenia*, although it is below the required value.

Salinity. One of the characteristics of water quality that has a significant impact on the organisms that thrive in marine environments is salinity. High water salinity in the range of 32 to 34 ppt is appropriate for usage in seaweed production. The seaweed thallus will grow slowly and age quickly if fluctuations are outside the ideal range. The agriculture area should not be near river mouths or other fresh water sources, which may change the salinity (Utojo et al 2004; Pongmasak & Sarira 2015). For the cultivation of *Halymenia*, salinities between 28 and 33 ppt are ideal (Wong & Chang 2000; Fadilah & Pratiwi 2020). The salinity measured during the investigation was between 29 and 33 ppt, being suitable for cultivating and maintaining *Halymenia*.

Dissolved oxygen. Aquatic biota is limited by DO, which controls its growth and activity (Karna 2003; Krisna & Saraswati 2016). The diffusion of oxygen from the open air and the products of photosynthesis by aquatic biota are the sources of oxygen in the waterways (Nugroho 2006). Aquatic organisms use DO as a resource for growth, fertilization, and reproduction (Lobban & Harrison 1997). Seaweed grows well when DO concentrations are between 3 and 8 ppm (Ariyati et al 2007; Pongmasak et al 2010). Cultured *Halymenia* could grow because the DO content in this study ranged from 4 to 6 ppm.

Conclusions. The cultivation of *Halymenia* using the mesh bag and non-mesh bag methods resulted in noticeably distinct effects on the seaweed's absolute weight growth and relative growth. The absolute weight growth and relative growth of *Halymenia* were both better when using the mesh bag method.

Conflict of Interest. The authors declare that there is no conflict of interest.

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