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Application of the Longline Method of Seaweed *Turbinaria ornata* Cultivation through Spacing Treatment

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ABSTRACT

The waters of Ternate Island, especially the waters of Kastela, have a large potential for seaweed availabilty in natural waters, but until now the development of cultivation has not been optimal due to the lack of information and technology of the right development method. Therefore, a sustainable cultivation development policy was needed. Seedling spacing is one of the technical factors that affect seaweed growth. The purpose of this study was to determine the application of the use of the longline method cultivation in supporting the development of seaweed *Turbinaria ornata* cultivation through planting distance treatment and determining the best planting distance. The construction of seaweed *Turbinaria ornata* cultivation is rectangular in size (25 x 10 m), made of polyethylene rope studded with concrete anchors. In the construction of the cultivation, there are five stretch ropes. Each stretch rope is installed with a distance of 25cm. The collection of seaweed seeds was carried out naturally by collecting seedlings from the research location, namely in the waters of Kastela, Ternate Island District. The collection of seaweed *T.ornata* seedlings was carried out at a depth of about 1 meter. The data analyzed were absolute weight growth data and relative growth rate. The results showed that planting distance had a very different effect on the growth of absolute weight and relative growth of seaweed *Turbinaria ornata*. The planting distance of 25cm gives the best results on the growth of absolute weight and relative growth of seaweed *Turbinaria ornata*.

INTRODUCTION

Seaweed is a plant with a high diversity of types. There are approximately 10,000 species of seaweed that belong to the group of red algae, green algae and brown algae. Based on its distribution and abundance, the brown seaweed (Phaeophyta) is the most widely found and generally widely used as a commercial extract in agricultural and horticultural applications **(Raj *et al.*, 2018)**. One type of brown seaweed that has important economic value is the type of *Turbinaria ornata*.

Moreover, *Turbinaria ornata* is one of the groups of brown macroalgae (Phaeophyta), which has a very important role in the industrial world as a raw material for alginate **(Guiry & Guiry, 2018)**. It has bioactive polysaccharides that are used for the pharmaceutical industry **(Handayani, 2018)**. *Turbinaria ornata* extract contains neophytadiene compounds, which have demonstrated activity as wound coverings (plasters) **(Oktaviani *et al*., 2019)**.

The limited technology of cultivating seaweed *Turbinaria ornata* with the right method causes its production to be suboptimal. One of the seaweed cultivation methods that needs to be tried is the longline method, where this method has advantages such as fast seaweed growth, cost-effective, and easy control **(Hernanto *et al*., 2015)**. This method is one of the surface methods that is in great demand by the community in carrying out seaweed cultivation **(Iskandar, 2019)**.

The waters of Ternate Island, especially the waters of Kastela, have a large potential for seaweed availablilty in natural waters, but until now the development of cultivation has not been optimal due to the lack of information and technology of the right development method. Therefore a sustainable cultivation development policy is needed. In addition, seaweed cultivation activities must be supported by factors that play a role in the sustainable growth and management of seaweed cultivation such as environmental, technological, social and economic. These influences; environmental, technological and socio-economic factors, will have an impact on the sustainability of seaweed cultivation in Kastela waters. Moreover, these factors will greatly determine the policy direction of seaweed development as one of the leading commodities **(Irfan & Abdullah, 2023)**.

Proper seaweed cultivation techniques are needed to increase the productivity of seaweed cultivation, one of which is by paying attention to the planting distance of clumps. Seedling spacing is one of the technical factors that affect the growth of seaweed due to its relationship with nutrient absorption and allows for a more optimal distribution of aquatic nutrients **(Fadilah & Pratiwi, 2020)**. Cultivation technology for seaweed *Turbinaria ornata* has not been widely developed, hence it was necessary to conduct research to obtain information on cultivation technology components in the form of clump planting distances that are suitable for growth **(Irfan & Abdullah, 2023)**. This study aimed to determine the application of the use of the longline cultivation method in supporting the development of seaweed *Turbinaria ornata* cultivation through planting distance treatment and determining the best planting distance for the growth of seaweed *Turbinaria ornnata*.

MATERIALS AND METHODS

This research was carried out in the coastal waters of Kastela, Ternate Island District, Ternate City. The maintenance of seaweed *Turbinaria ornata* was carried out for 45 days from April to June 2024. The construction of seaweed *Turbinaria ornata* cultivation is rectangular in size (25 x 10m), made of polyethylene rope studded with concrete anchors. In the construction of the cultivation there are five stretch ropes. Each stretch rope is installed with a distance of 25cm. The collection of seaweed seeds was carried out naturally by collecting seeds at the research site, namely in the waters of Kastela, Ternate Island District. Moreover, the seeds obtained were then accommodated in colbox containers to be subsequently used for planting. The collection of seaweed *T.ornata* seedlings was carried out at a depth of about 1 meter. The seedlings, each with an initial weight of 50 grams, were tied to each point along the rope in each ris rope/span rope system. The placement of seaweed *Turbinaria ornata* cultivation containers with the longline method was carried out at a depth of 1 meter.

In this study, 3 spacing treatments were tried. The treatments tried were: Treatment A: Planting distance 15cm, Treatment B: Planting distance 20cm, Treatment C: Planting distance 25cm. Each treatment was repeated 3 times, hence there were 9 experimental units (Fig. 1).

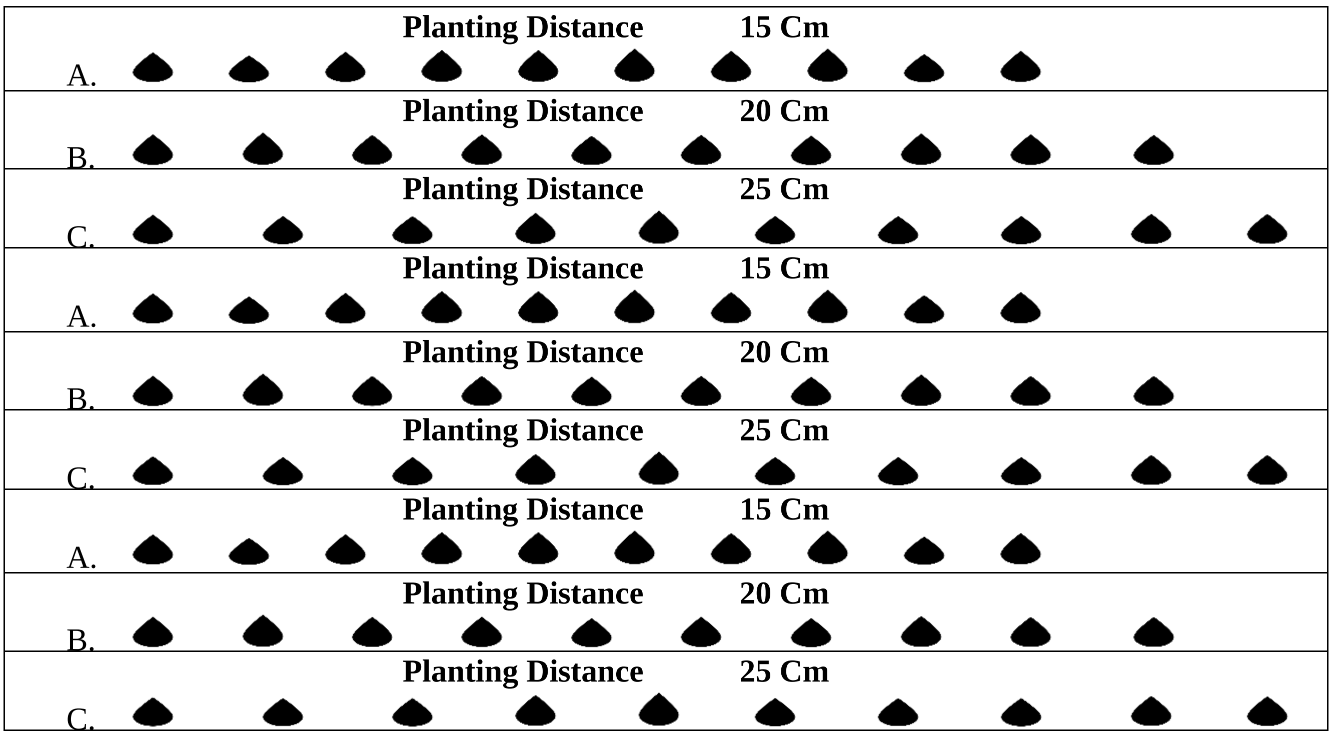

Fig. 1. Lay out treatment at each planting distance of seaweed *Turbinaria ornata*

Observation of the weight gain of the seaweed thallus *Turbinaria ornata* was carried out every week on each stretch rope, then the data were recorded. Aquatic environmental parameters, including temperature, current speed, pH, and salinity, were observed weekly. Temperature, pH, and salinity were measured using a Hanna-Horiba water checker, while current speed was assessed using a ping-pong ball and a stopwatch. Data analysis was used to determine the growth of seaweed *Turbinaria ornata* cultivated by the longline method. The data analyzed included absolute weight growth data, which was obtained from the difference between the average weight at the end of maintenance and the initial weight when stocked/planted and the relative growth rate.

The absolute weight growth was calculated using the formula from **Irfan and Subur (2022)** as follows:

$$W = Wt - Wo$$

Where:
W = Growth (Growth in absolute weight) (grams)
Wt = Final weight (grams)
Wo = Initial weight (grams)

The growth rate was calculated (relative growth rate) using the formula from **Dharmawaty *et al.* (2016)** as follows:

$$LPN = Ln \frac{(Wt - Wo)}{t} \times 100\%$$

Where:
LPN = Growth rate (%)
Wo = *T.ornata* wet weight at the start of the study (grams)
Wt = *T.ornata* wet weight at the end of the study (grams)
t = maintenance time (45 days)

The design employed in this study was a completely randomized design (CRD). Data analysis was conducted using analysis of variance, following the methods outlined by **Steel and Torrie (1993)**. Before the data were tested, a normality test was carried out using the Kolmogorof Smirnov test to ensure that the data were distributed normally. The data were analyzed using SPSS version 23 software.

RESULTS

1. Absolute weight growth

The average growth of the absolute weight of seaweed *Turbinaria ornata* based on planting distance with the longline method can be seen in Fig. (2).

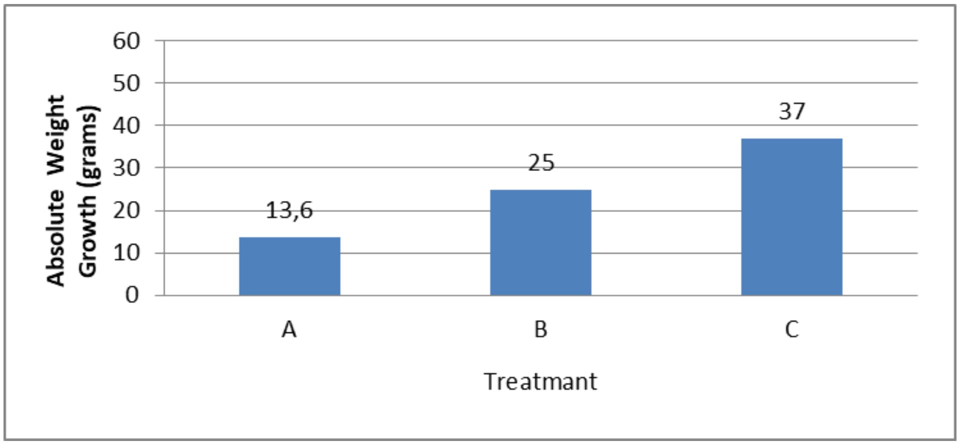

Fig. 2. Average growth in absolute weight of *Turbinaria ornata*

Fig. (2) shows the absolute weight growth of seaweed *Turbinarai ornata* with different longline methods in each treatment, namely treatment A (planting distance 15cm) of 13.6 grams, treatment B (planting distance 20cm) of 25 grams, and treatment C (planting distance of 25cm) of 37 grams.

Based on the average value of absolute weight growth, it shows that treatment C has a higher average absolute weight growth value than treatment B and A.

To see the difference in the influence of each treatment of the absolute weight growth of seaweed *Turbinaria ornata*, a variety analysis was carried out whose results are shown in Table (1).

Table 1. Results of fingerprint analysis of absolute weight growth variety of seaweed *Turbinaria ornate*

Source of diversity	**Degrees of freedom**	**Squared sum**	**Middle square**	**F count**	**F table**	
					0.05	**0.01**
Treatment	2	0.817	0.4085	22.081**	5.14	10.32
Error	6	0.037	0.0185			
Total	8					

Information : ** = very different indeed.

Table (1) shows that the value of F calculated (22.081) is > from F tables 0.05 and 0.01, hence the effect is very different on the growth of the absolute weight of seaweed *Turbinaria ornate*. Therefore, the treatment tried has a very different effect on the growth of the absolute weight of seaweed *Turbinaria ornata*. Since there is a very different effect, it is necessary to carry out the smallest real difference (BNT) test with the aim of finding out the difference in the effect of each treatment whose results can be seen in Table (2).

Table 2. LSD test results effect of each treatment on the growth of seaweed *Turbinaria ornata* absolute weight

Treatment	Average	Difference		LSD	
				0.05	0.01
C	37	-		0.271	0.407
B	25	12^{**}	-		
A	13.6	23.4^{**}	$11,4^{**}$		

Information : ** = very different indeed.

Table (2) shows significant differences between treatments. Specifically, the comparison of treatment C to B, and C to A, reveals notable variations, with treatment C outperforming both B and A. The LSD test results indicate that treatment C yields the best absolute weight growth for the seaweed *Turbinaria ornata*.

2. Relative growth

The results of the analysis of the relative growth of seaweed *Turbinaria ornata* using the longline method can be seen in Fig. (3).

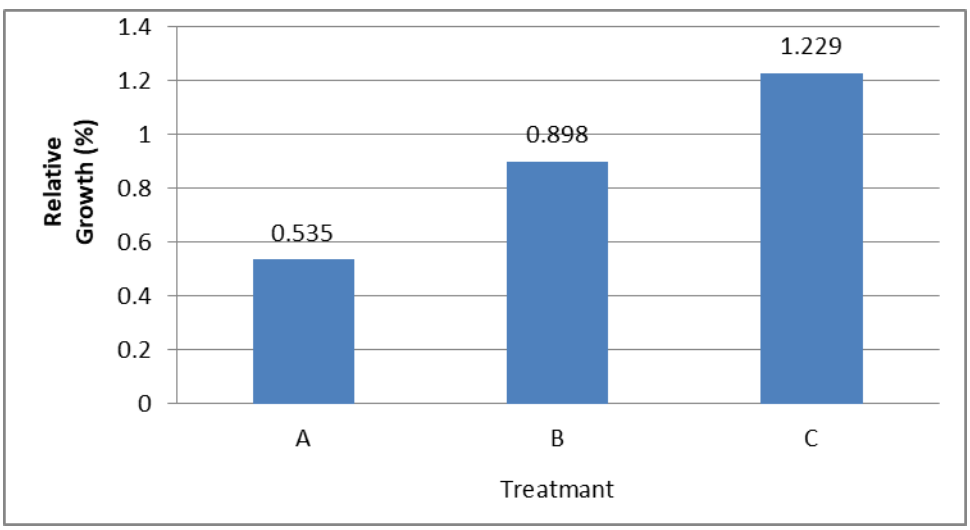

Fig. 3. Average growth relative of *Turbinaria ornata*

Fig. (3) shows that the relative growth value of seaweed *Turbinaria ornata* varies. Treatment A (planting distance of 15cm) had a relative average growth value of 0.535%, treatment B (planting distance of 20cm) of 0.898% and treatment C (planting distance of 25cm) of 1.229%. From the average relative growth in each treatment, it was shown that treatment C (planting distance of 25cm) had the highest value of 1.229% compared to treatment B and treatment A. To see the difference in the influence of each treatment, a variety analysis was carried out, as shown in Table (3).

Table 3. Fingerprint analysis of relative growth varieties of seaweed *Turbinaria ornata*

Source of diversity	**Degrees of freedom**	**Squared sum**	**Middle square**	**F Count**	**F table**	
					0.05	**0.01**
Treatment	2	0.724	0.362	70.980**	5.14	10.32
Error	6	0.031	0.0051			
Total	8					

Information : ** = very different indeed.

Table (3) shows that the value of F count (70.980) > F table 0.05 and F table 0.01, hence it has a very different effect on the relative growth of seaweed *Turbinaria ornata*. Since there is a very different effect, it is necessary to carry out a further test of the smallest real difference (LSD) with the aim of finding out the difference in the effect of each treatment whose results can be seen in Table (4).

Table 4. LSD test results effect of each treatment on the relative growth of seaweed *Turbinaria ornata*

Treatment	**Average**	**Difference**		**LSD**	
				0.05	**0.01**
C	1.229	-		0.142	0.216
B	0.898	0.331**	-		
A	0.535	0.694**	0.363**		

Information : ** = very different indeed.

Table (4) indicates significant differences between treatments. Specifically, the comparison of treatment C to B, and C to A, shows substantial variation, with treatment C demonstrating superior results. The LSD test results confirm that treatment C provides the best relative growth for the seaweed *Turbinaria ornata*.

3. Water quality

The results of water quality parameters during the study are presented in Table (5).

Table 5. Water quality during research

Parameter	**Range**
Temperature (°C)	27 - 32
Current speed (cm/sec)	28 - 40
pH	6.5 - 7.2
Salinity (‰)	25 – 32

DISCUSSION

Based on the data in Table (1), the average value of each planting distance treatment varies from one to another. If the planting distance on the rope is longer, it will provide more opportunities and space for seaweed to absorb nutrients in the waters. In addition, the length of the distance will help facilitate the photosynthesis process because each branch has the same opportunity to get sunlight. This is in accordance with the statement of **Pongmasak and Sarira (2018)** that the distance between seaweed planting on the rope generally ranges from 20- 25cm. If the planting distance is too short, there will be many seaweed ties so that the opportunity of each branch of seaweed to obtain nutrients as a food source is needed little, and this will slow down its growth.

Planting distance is related to the unity of land area. The planting distance used, in addition to affecting the traffic of water movement, will also avoid the accumulation of dirt on the thallus which will help aeration so that the photosynthesis process necessary for seaweed growth can take place **(Pongmasak & Sarira, 2018)**. According to **Abdan *et al*. (2013)**, the competition between thallus in terms of sun needs, nutrients and movement space greatly affects the growth of seaweed.

The high absolute weight growth in treatment C (25cm planting distance) caused by 25cm planting distance significantly affects the growth of seaweed weight from the aspect of nutrient supply. The distance between seaweed plants can influence competition for nutrients essential for growth, including sulfur, silicon, phosphorus, calcium, iron, iodine, and bromine. **Fadilah and Pratiwi (2020)** supports this by noting that the growth of seaweed is affected by the spacing of seedlings. **Darmawati *et al*. (2016)** stated that planting distance affects the traffic of water movement and will avoid the accumulation of manure on the thallus, which will help aeration so that the photosynthesis process necessary for seaweed growth can take place and prevent large fluctuations in salinity and water temperature.

At a planting distance of 15cm, seaweed *Turbinaria ornata* relatively shows a growth in absolute weight that tends to decrease. **Prihaningrum *et al*. (2001)** stated that the wider the planting distance, the wider the movement of water that carries nutrients so that the growth of seaweed can increase. This statement is in line with the results of the research obtained where the wider the planting distance, the higher the absolute weight growth achieved.

The low growth of the absolute weight of *Turbinaria ornata* at a planting distance of 15cm is due to the fact that at the planting distance, after maintenance of up to three weeks the thallus of *Turbinaria ornata* is intertwined so that it will affect the movement of water carrying nutrients, hence the nutrient absorption process does not take place properly. At a planting distance of 15cm, the presence of many micro plants (moss) and mud, along with animal attachments, results in the slow growth of *Turbinaria ornata*. This is due to competition for nutrients between the seaweed and the micro plants (moss). This condition is in accordance with the opinion of **Anggadiredja *et al*. (2006)**, who stated that the plants in the cultivation plants are competitors, thus interfering with the growth of seaweed.

The highest relative growth was found in treatment C (planting distance 25cm) compared to treatment B (planting distance 20cm) and treatment A (planting distance 15cm). The highest relative growth was found in C treatment (planting distance of 25cm) which had the highest average relative growth value of 1.229%, which means that the relative growth of seaweed *Turbinaria ornata* every day increased by 1.2295%. In general, the average value of each treatment obtained shows that the cultivation business carried out through this study is not profitable since the average value of each treatment is still below the standard value of 3%. This is in line with the statement of **Desy *et al.* (2016)**, which stated that a seaweed cultivation activity is said to be profitable if it has an additional relative growth rate or a daily growth rate of at least 3%.

Temperature has an important role for the life and growth of seaweed. Water temperature can affect several physiological functions of seaweed such as photosynthesis, respiration, growth, and reproduction **(Pongmasak & Sarira, 2018)**. Temperature has an important role in the seaweed growing process. According to **Musadat and Afandi (2018)**, the water temperature that is suitable for the needs of seaweed life ranges from 28- 32^{o}C. A high temperature rise will cause seaweed thallus to become pale and yellowish, unhealthy, wilted and very susceptible to disease. Moreover, temperature has a direct effect on seaweed life, especially in the process of photosynthesis. A very high level of fluctuation will make the seaweed stressed, affecting its growth rate **(Pongmasak & Sarira, 2018)**.

The average temperature value at the research site ranged from 27- 320^{o}C (Table 5). Additionally, the water temperature for the *Turbinaria* life in general is between 26-340^{o}C **(Irfan & Abdullah, 2024)**. The value of the temperature range obtained is still considered suitable for seaweed cultivation.

The location for seaweed cultivation must be protected from currents (water movement) and waves that are too strong. Astounding currents and waves will damage and wash away plants **(Pongmasak & Sarira, 2018)**. The speed of the current is an important factor in seaweed cultivation since it functions to deliver nutrients to seaweed. The required current speed must match the life of the seaweed. According to **Musadat and Afandi (2018)**, a good water flow will bring nutrients for seaweed to grow and to clean up dirt and sediment that sticks. In addition, seaweed will also grow well since there is an opportunity to absorb nutrients (food) from water and the photosynthesis process is not disturbed. The speed of the current is too strong and causes plants to have difficulty absorbing nutrients (food) that are useful for growth.

The current speed value in the range of 20-40cm/ sec is very good to support the growth and development of seaweed, while the current speed greater than 40cm/ sec can destroy seaweed cultivation containers and can break seaweed branches **(Irfan & Subur,**

2022). The current speed measured in this study ranged from 28-40cm/ sec (Table 5), hence it still supports the growth of seaweed *Turbinaria ornata*.

pH is a limiting factor for the life and existence of a plant. Although seawater has a relatively stable pH value, it can be affected by photosynthesis activities, temperature, and industrial waste. The optimal aquatic pH for seaweed cultivation is generally 7.3 - 8.2 **(Pongmasak & Sarira, 2015)**.

Cultivated organisms have adaptations to pH values. The measured pH is around 6.5- 7.2 (Table 5). The optimal pH for *Turbinaria* cultivation ranges from 6.5- 8.4 **(Irfan & Abdullah, 2024)**. Thus, the pH value obtained still supports the growth and survival of the cultivated *Turbinaria ornata* seaweed.

Each marine organism has a different tolerance range to salinity including *Turbinaria ornata*, hence salinity is one of the important factors that affect the survival and growth of organisms. According to **Pongmasak and Sarira (2018)**, the salinity range of seaweed growth can thrive in tropical areas that have aquatic salinity of 32-34ppt. However, if the fluctuation is outside the ideal range, it will cause low growth and rapid aging of seaweed. To get salinity with this range, the cultivation location should not be close to river mouths or other freshwater sources.

The results of salinity measurements during the study were obtained in the range of 25- 32 ‰ (Table 5). Moreover, the optimal salinity for *Turbinaria* is in the range of 28-35ppt **(Irfan & Abdullah, 2024)**. From the salinity values obtained, it shows that the range of salinity obtained still supports the feasibility and survival of seaweed *Turbinaria ornata*.

CONCLUSION

Based on the results of the study, it was shown that planting distance had a very different effect on the growth of absolute weight and relative growth of seaweed *Turbinaria ornata*. The planting distance of 25cm gives the best results on the growth of absolute weight and relative growth of seaweed *Turbinaria ornata*. This planting distance also needs to be tried on other types of seaweed.

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