JOURNAL OF AGRICULTURAL PRODUCTION
https://agriprojournal.com ISSN: 2757-6620

RESEARCH ARTICLE

A Preliminary Study on the Cultivation of Brown Seaweed *Sargassum cristaefolium* Using Fixed-off Bottom and Raft Methods

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ARTICLE INFO

Article History
Received: 03.03.2022
Accepted: 24.04.2022
First Published: 10.05.2022

Keywords
Fixed-off bottom method
Raft method
Sargassum cristaefolium
Specific growth rate
Survival rate

ABSTRACT

Sargassum is a great source of alginate, a phycocolloid with vast uses in nutraceutical and pharmaceutical areas. Hence, the cultivation techniques of this species need special attention and are worth investigating. In this study, a preliminary study on the cultivation of *Sargassum cristaefolium* was carried out in coastal water of Pasiagan, Bongao, Tawi-Tawi, southern Philippines, using fixed-off bottom and raft methods with two types of seedlings (T_1 = with holdfast and T_2 = vegetative cutting). Results revealed that the specific growth rate (SGR) of T_1 (-1.51±0.6% day^{-1}) and T_2 (-2.03±0.23% day^{-1}) in the fixed-off bottom method did not significantly differ (p>0.05) after 45 days of culture. In raft method, SGR of T_1 (1.5±0.12% day^{-1}) and T_2 (1.12±0.40% day^{-1}) did not significantly vary (p>0.05) after 45 days. The survival rate of T_1 (43.33±6.67%) was greatly higher (p>0.05) than T_2 (13.33±3.33%) after day 45 cultured in the fixed-off bottom method. However, the survival rate of T_1 (30.01±15.27%) and T_2 (16.68±12.01%) did not differ significantly in the raft method. This study suggests that both seedling types can be used in raft method for *Sargassum* cultivation. This study would serve as preliminary information on the cultivation of *Sargassum* in Tawi-Tawi, southern Philippines.

Please cite this paper as follows:

Yangson, N. A. T., Edubos, J. I., Tahiluddin, A. B., Toring, C. C., & Toring-Farquerabao, M. L. B. (2022). A preliminary study on the cultivation of brown seaweed *Sargassum cristaefolium* using fixed-off bottom and raft methods. *Journal of Agricultural Production*, *3*(1), 17-29. https://doi.org/10.29329/agripro.2022.413.3

Introduction

Sargassum is a class of Phaeophyceae in the order Fucales, which is composed of 359 officially accepted species (Guiry & Guiry, 2022). It consists of a higher amount of protein, essential and non-essential amino acids that carry out many bodily functions, necessary fatty acids, and minerals than kelp (Laminariales). Phycocolloids (alginate), bioactive compounds, and polyphenols isolated from different *Sargassum* species may have possible nutraceutical and medicinal use (Nisizawa, 2002; Gupta et al., 2011; Namvar et al., 2013), and is an effective immunostimulant against *Aeromonas hydrophila* in rainbow trout (Sönmez et al., 2021). Hence, *Sargassum* spp. have a great possibility to be used as ingredients in pharmaceutical to nutraceutical areas (Yende et al., 2014). *Sargassum* is extensively distributed in tropical and temperate waters, particularly in the Indo-West Pacific region and Australia (Cheang et al., 2008). It is distinct and forms vast beds along the rocky shores (Marquez et al., 2014).

Sargassum is commonly cultivated in Japan, Korea, and China and is utilized as human food (sea vegetables) and as medicine (Nanba et al., 2008; Yu et al., 2013; Redmond et al., 2014; Kim et al., 2017; Amlani & Yetgin, 2022). In Indonesia,

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Wahyuningtyas et al. (2018) showed that 25 cm plantation depth using the longline method has highly increased the growth rate of *Sargassum*. Longline is a traditional culture method in Korea where 5-10 cm of *Sargassum* seedlings were inserted into a rope at an interval of 5-10 cm (Pang et al., 2008). In China, the zygote of *S. hornerie* cultured in a polypropylene tank reached 5-7 cm, while in suspension culture, the seedlings reached a size of 1.5-2.5 cm after 3 months (Pang et al., 2006). Furthermore, the incorporation of nutrient enrichment showed to increase the *Sargassum* productivity (Feibel, 2016), similar response to other seaweeds (Harrison & Hurd, 2001; Tahiluddin et al., 2021a; Tahiluddin et al., 2021b). For instance, in Florida (USA), growth rates of both *S. fluitans* and *S. natans* cultured in a shipboard flowing seawater culture system and in situ cages in the western Sargasso Sea had reached 0.03 to 0.04 doublings day^{-1} enriched with nitrate or ammonium; while in phosphate enrichment, growth rate ranged from 0.05 to 0.08 doublings day^{-1} (Lapointe, 1986). In the Philippines, different species of *Sargassum* are mainly harvested from the wild, and studies on *Sargassum* cultivation are still in their infancy. Recently, an initial experiment on the cultivation of *Sargassum* in the Philippines was conducted, particularly in the study of Aaron-Amper et al. (2020) in Bohol, central Philippines, where a zygote of *S. aquifolium* was successfully produced in the hatchery and reared its germlings in the field out-planting using various substrates.

The seaweeds in the Philippines are remarkably diverse, with more than 800 species recorded (Silva et al., 1987; Tahiluddin & Terzi, 2021). Harvesting of *Sargassum* spp. in the Philippines is mainly dependent on the wild population, which is generally used as a liquid fertilizer and animal feed. In addition, *S. cristaefolium* showed a promising result as potential organic fertilizer for *Kappaphycus* (Irin, 2019). Species of *Kappaphycus, Eucheuma*, *Caulerpa,* and *Gracilaria* are the primary cultivated seaweed species in the country (Trono & Largo, 2019). In Tawi-Tawi, southern Philippines, seaweed diversity is high, with 79 species recorded, including *Sargassum* spp. (Puig-Shariff, 2015). Since the 1970s, only *Kappaphycus* and *Eucheuma* spp. have been commercially cultivated in Tawi-Tawi using the line and stake methods, which are considered one of the major livelihoods for coastal villagers. *Sargassum* spp. are potential cultured seaweed species and are only collected and used as cover during the transport of *Kappaphycus* species in Tawi-Tawi (Sarri et al., 2022). However, there is a limited existing study on the cultivation of *Sargassum*. Thus, a preliminary study was conducted on the growth and survival rate of brown seaweed (*S. cristaefolium*) cultivated in the coastal water of Pasiagan, Bongao, Tawi-Tawi, southern Philippines, using fixed off-bottom and raft methods.

Materials and Methods

Study Site and Time

The study was conducted along the coastal water of Pasiagan, Bongao, Tawi-Tawi, southern Philippines (Figure 1) with a duration of 45 days from February 17 to April 03, 2019.

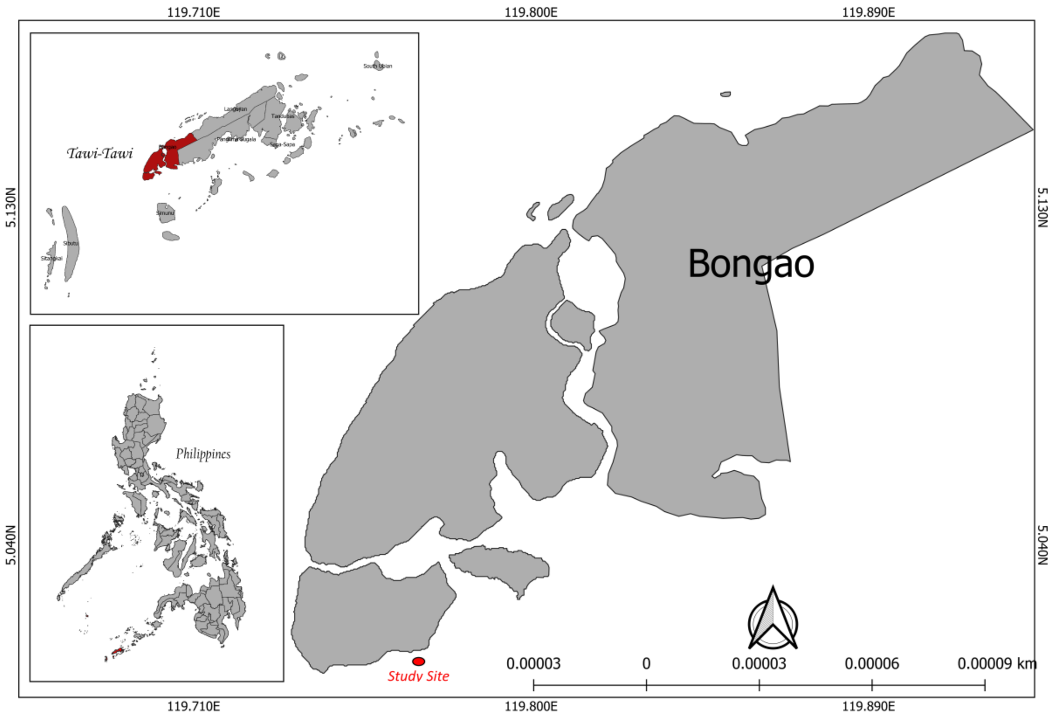

Figure 1. Map showing the study site.

Preparation of the Farm Site

The study site was cleaned from all obstacles, predators like sea urchins and starfishes by removing them one by one in the farm site to avoid grazing.

Source of Seedlings and Conditioning

The seedlings of *S. cristaefolium* were collected from the Sunkist beachside area in Sanga-Sanga, Bongao, Tawi-Tawi, southern Philippines. The freediving technique was used to collect these samples. The whole part of the seaweed, including holdfasts, was included and was immediately placed into styrofoam boxes filled with seawater, then transported to the culture area. Acclimatization was done by submerging the box slowly into the sea of the farm site allowing the seawater to mix with the water in the box for 10 minutes. The acclimatization period was done 6 days before the actual planting.

Preparation of Seedlings

There were two types of seedlings used in the study as treatments, Treatment I (T_1) for the seedlings with holdfast and Treatment II (T_2) for vegetative cutting. The T_1 has a corresponding range of 40-50 g with an initial length of 13-36 cm. While for T_2, the seedlings were cut into 40-50 g using a knife with an initial length of 14-32 cm. For the fixed-off bottom method, seedlings in both treatments were tied into a 2.5 m rope line with an interval of 25 cm. T_1 was individually tied in available stones or broken corals using a soft tie, while T_2 was directly tied in a rope. For the raft method, seedlings in both treatments were tied up to a sand-filled plastic bottle (500 ml) with 25 cm rope. These were placed in a basin and transported to the farm site.

Planting of Seedlings

For the fixed-off bottom method, the seedlings in both treatments were randomly planted following Hurtado et al. (2008) with few modifications. The lines were stretched and attached to stakes, where the seedlings touched the seabed (Figure 2). For the raft method, the seedlings were randomly planted following Wahyuningtyas et al. (2018). Seedlings were hanged in a 2.5 m bamboo with a distance interval of 25 cm and a depth of 25 cm below the sea surface (Figure 3).

Experimental Designs

The applied design in this study was Randomized Complete Block Design (RCBD) with 2 treatments, and it was triplicated per treatment for both methods.

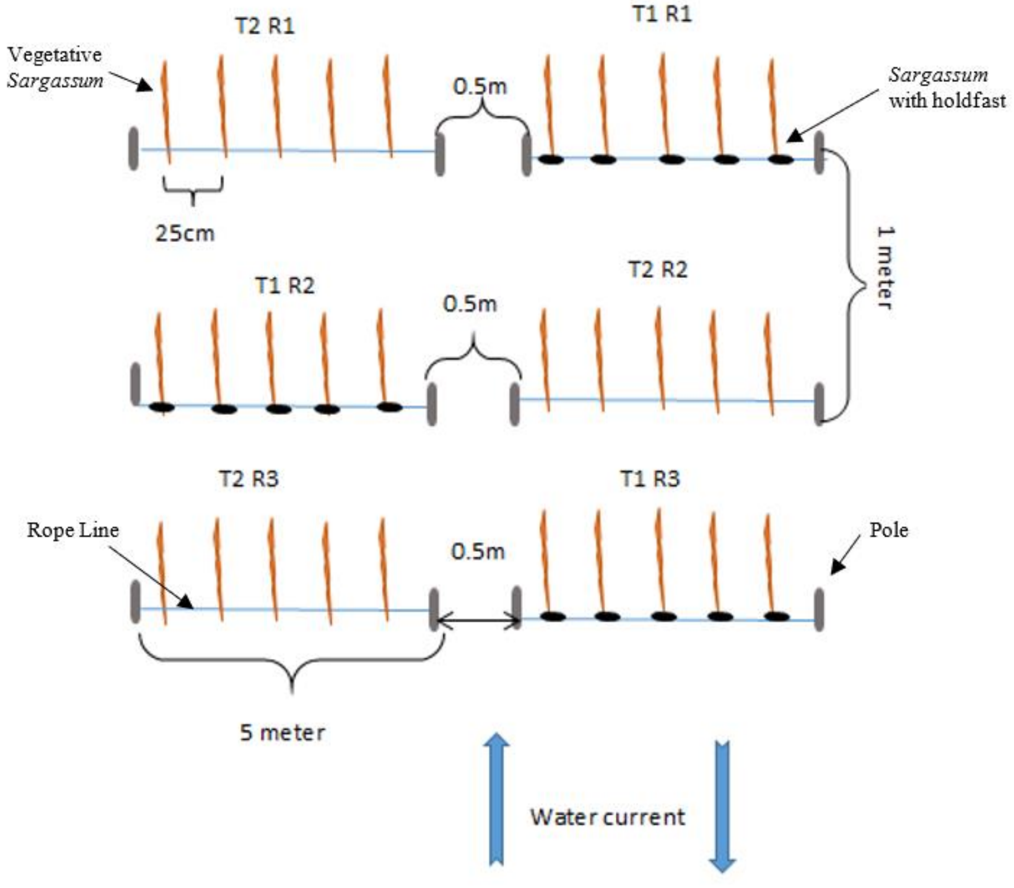

Figure 2. Lay-out of fixed-off bottom method of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting, $R_{1,2,3}$ =replicates).

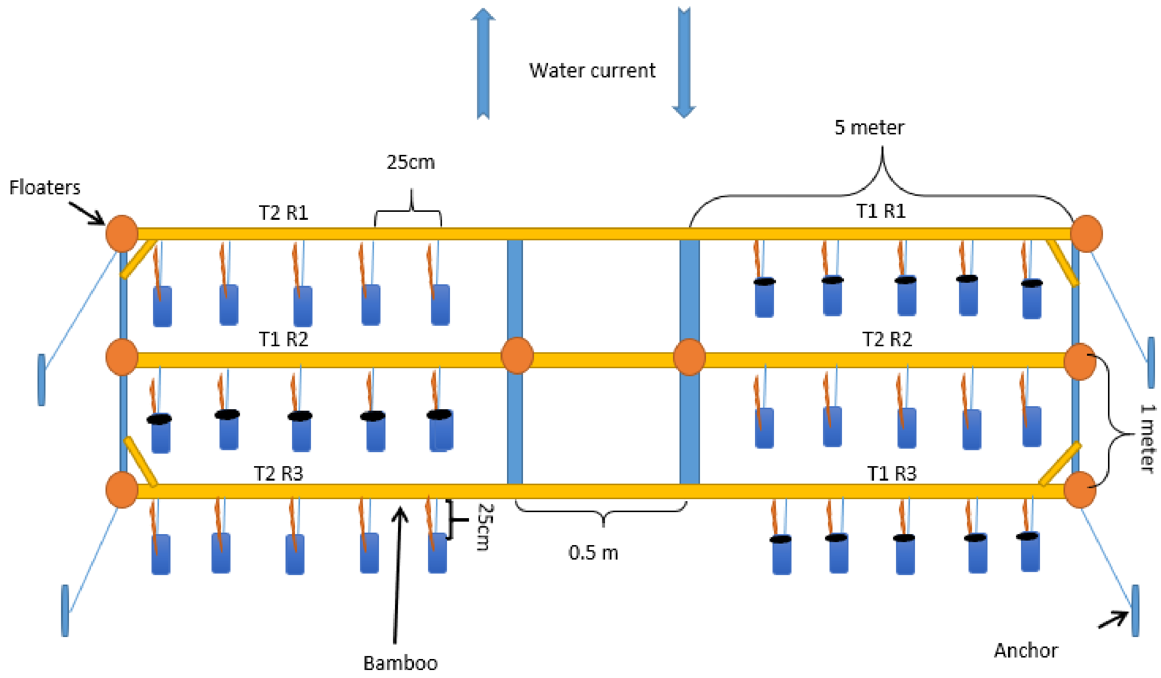

Figure 3. Lay-out of raft method of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting, $R_{1, 2, 3}$ =replicates).

Sampling

Growth rate

The growth rate of seedlings was obtained after 45 days of culture. All seedlings were harvested. Weighing of the samples was done by patting them with a white cloth, and they were then put on a digital weighing scale. The length of the samples was measured every 15 days by measuring the seedlings one by one starting from its lower tip up to the upper tip of the *Sargassum* using a meter stick. Mean weight and length were computed every 15 days. Using the formula of Luhan et al. (2015), growth (μ) expressed as a specific growth rate (SGR) was determined at the end of the study. SGR was calculated as follows:

$$\mu = \frac{\text{In (Wf)} - \text{In (Wi)}}{\text{Days of culture}} \text{ x } 100 \qquad (1)$$

Where,

W_f = final weight

W_i = initial weight

Survival rate

Monitoring of the survival rate was done every 15 days by checking and counting the mortality of the seaweeds. Missing bunches were considered mortality. The survival rate was computed using the formula below.

$$\text{Survival rate} = \frac{\text{Final number of seaweeds}}{\text{Initial number of seaweeds}} \text{ x } 100 \qquad (2)$$

Monitoring of Water Parameters

The water parameters such as temperature, salinity, and pH were measured every 7 days (9:00 A.M. – 12 P.M.) using a thermometer, refractometer (Atago Master), and pH meter (Smart Sensor), respectively. Water current and depth were determined using improvised drogue and calibrated rope, respectively.

Data Analysis

A t-test was applied to determine the significant difference between the means of two treatments in terms of growth and survival rates using SPSS software version 20. Data were presented as mean±SE (standard error). The level of significance used in the study was 0.05.

Results

Growth

Fixed-off bottom method

The specific growth rate (SGR) of *S. cristaefolium* (T_1 = with holdfast and T_2 = vegetative cutting) cultured in the fixed-off bottom method is shown in Figure 4. T_1 and T_2 attained SGR of -1.51±0.6% day^{-1} and -2.03±0.23% day^{-1}, respectively. Analysis using a t-test showed no significant difference (p>0.05) between the treatments. The mean weight is shown in Figure 5. After 45 days of culture, the t-test revealed no significant difference (p>0.05) between the treatments, with mean weights of 33.89±9.14 g (T_1) and 20.50±2.18 g (T_2). The average length between sampling periods is shown in Figure 6. There was no significant difference (p>0.05) in T_1 from day 0 to 30, day 0 to 45, day 15 to 30, and day 30 to 45. But, T_1 significantly increased (p<0.05) from day 0 to 15 but significantly decreased (p<0.05) from day 15 to 45. The average length of T_2 did not significantly change (p>0.05) from day 0 to 15, day 0 to 30, day 15 to 30, and day 30 to 45. However, there was a significant increased (p<0.05) from day 0 to 45 and day 15 to 45.

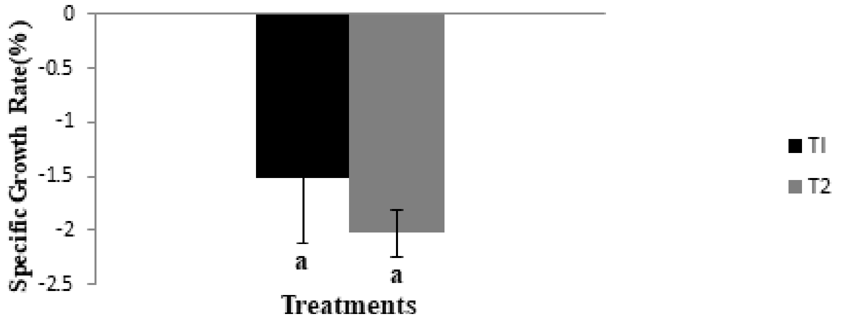

Figure 4. SGR of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting) cultured in fixed-off bottom method after 45 days. Bars with the same letters are not significantly different (p>0.05). Error bars in SEM (standard error of the mean), n= 17-60.

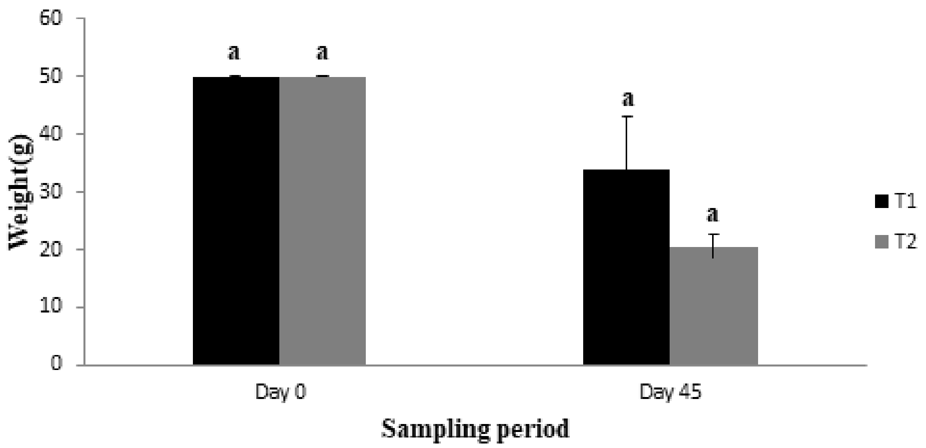

Figure 5. Mean wet weight of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting) cultured in fixed-off bottom method after 45 days. Bars with the same letters are not significantly different (p>0.05). Error bars in SEM (standard error of the mean), n= 17-60.

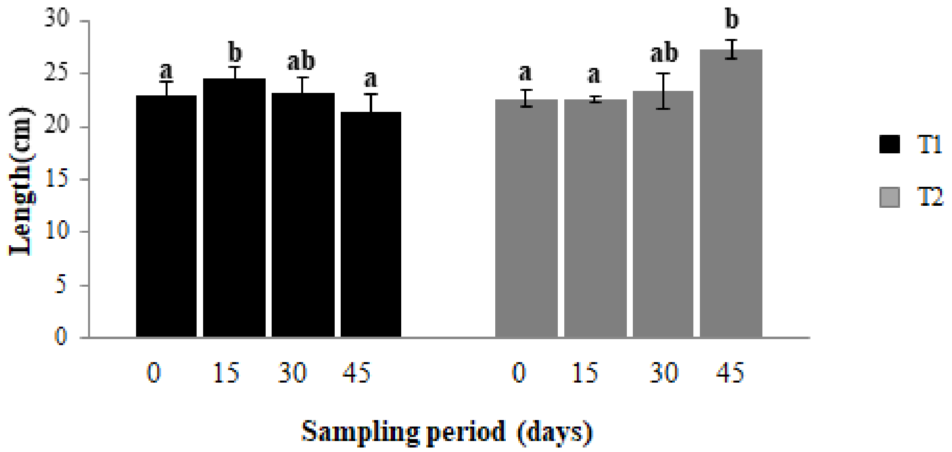

Figure 6. Average length in every sampling period of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting) cultured in the fixed-off bottom method for 45 days. Bars with different letters are significantly different (p<0.05). Error bars in SEM (standard error of the mean), n=17-60.

Raft method

The SGRs of *S. cristaefolium* in T_1 (with holdfast) and T_2 (vegetative cutting) cultured in the raft method were 1.5±0.12% day^{-1} and 1.12±0.40% day^{-1}, respectively (Figure 7). A t-test revealed no significant difference (p>0.05) among the treatments. After 45 days of culture, no significant difference (p>0.05) showed among the treatments, with mean weights of 110.07±0.68 g for T_1 and 86.25±12.75 g for T_2 (Figure 8). A t-test analysis revealed that the average length of T_1 did not significantly change (p>0.05) from day 0 to day 45. The average length of T_2 significantly increased (p<0.05) from day 0 to 15 and day 0 to 30. However, there was no significant change (p>0.05) from day 0 to 45, day 15 to 30, and day 30 to 45 (Figure 9).

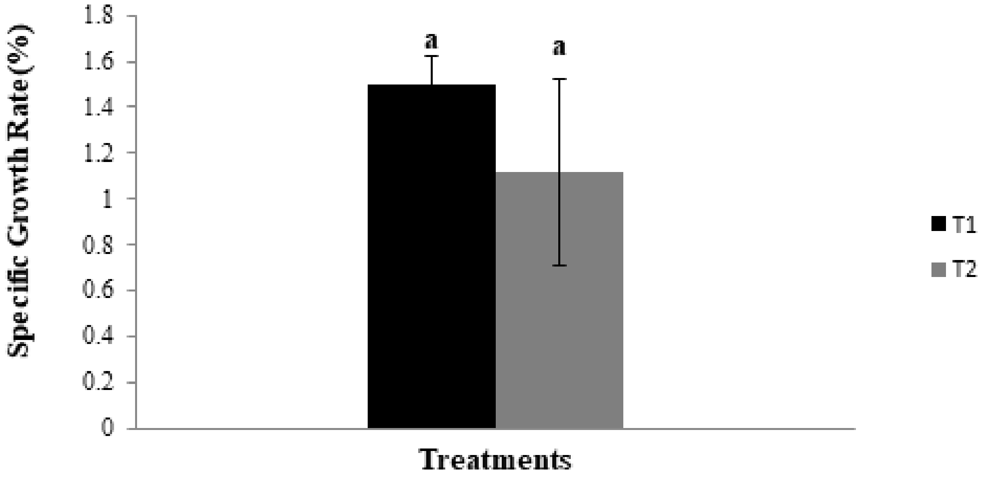

Figure 7. SGR of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting) cultured in raft method after 45 days. Bars with the same letters are not significantly different (p>0.05). Error bars in SEM (standard error of the mean), n=14-60.

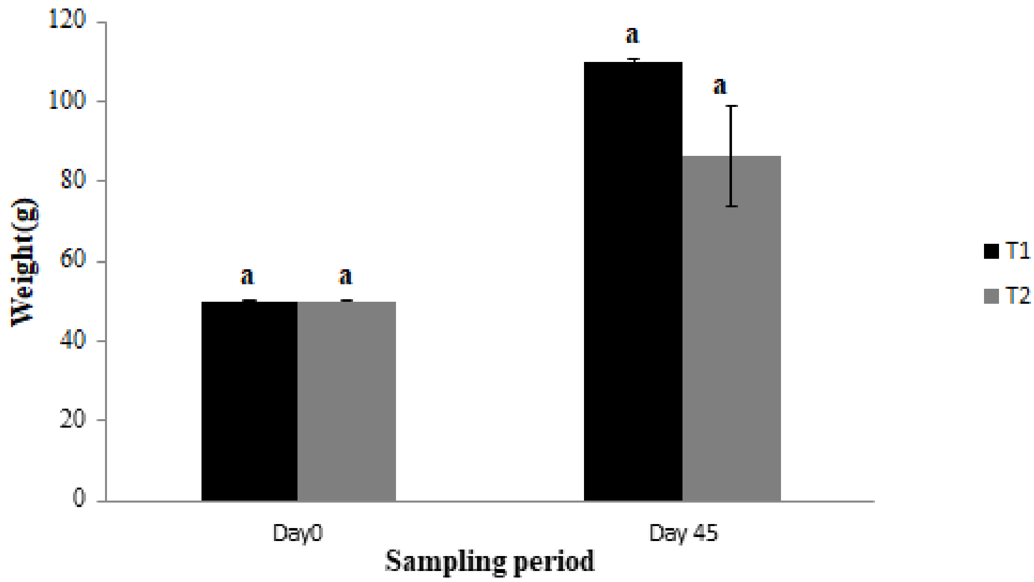

Figure 8. Mean wet weight of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting) cultured in raft method after 45 days. Bars with the same letters are not significantly different (p>0.05). Error bars in SEM (standard error of the mean), n=14-60.

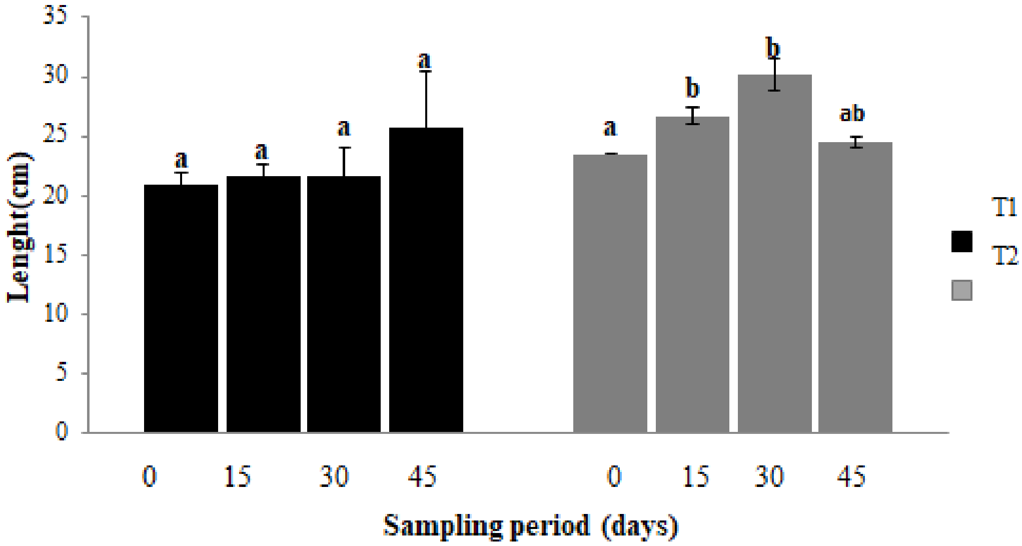

Figure 9. Average length in every sampling period of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting) cultured in raft method for 45 days. Bars with different letters are significantly different (p<0.05). Error bars in SEM (standard error of the mean), n=14-60.

Survival Rate

Fixed-off bottom method

The survival rate of *S. cristaefolium* in T_1 (96.65±3.33%) showed no significant difference (p>0.05) from T_2 (100±0%) on day 15 (Figure 10). However, the survival rate of T_1 (80±5.77%) was higher (p<0.05) than T_2 (46.67±6.67%) at day 30. At day 45, the survival rate of T_1 (43.33±6.67%) was also significantly higher (p<0.05) compared to T_2 (13.33±3.33%). The change in the survival rate of *S. cristaefolium* is shown in Figure 11. In T_2, the survival rate did not significantly change (p>0.05) from day 0 to 15, day 0 to 30, and day 15 to 30. However, the survival rate in T_1 significantly decreased (p<0.05) from day 0 to 45, day 15 to 45, and day 30 to 45. There was no significant change (p>0.05) in T_2 from day 0 to 15, but from day 0 to 30, day 15 to 30, and day 30 to 45, survival rates significantly decreased (p<0.05). From day 0 to 45, day 15 to 45, survival rates of T_2 significantly dropped (p<0.05).

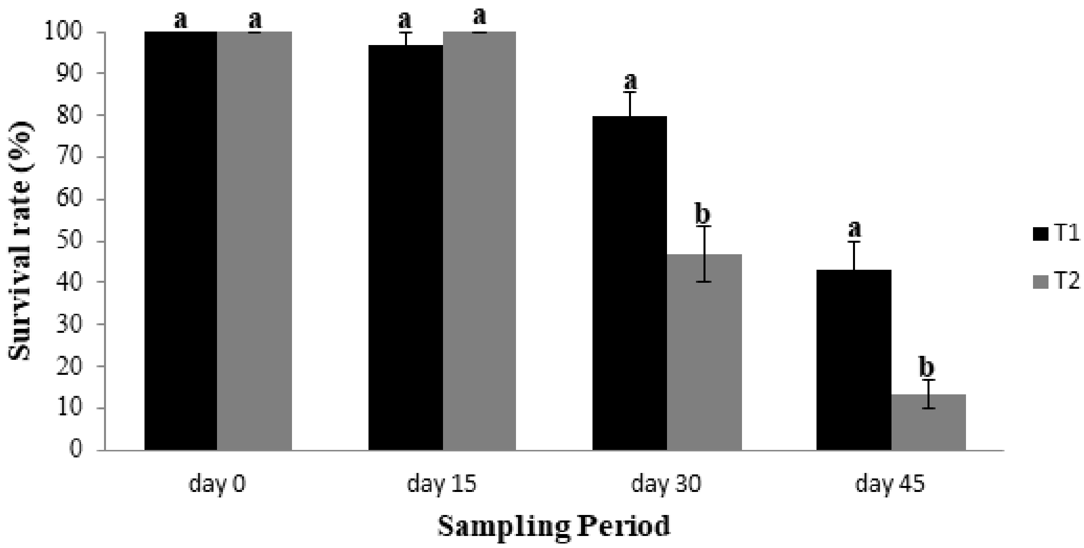

Figure 10. Survival rate of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting) cultured in the fixed-off bottom method for 45 days. Bars with different letters are significantly different (p<0.05). Error bars in SEM (standard error of the mean), n= 17-60.

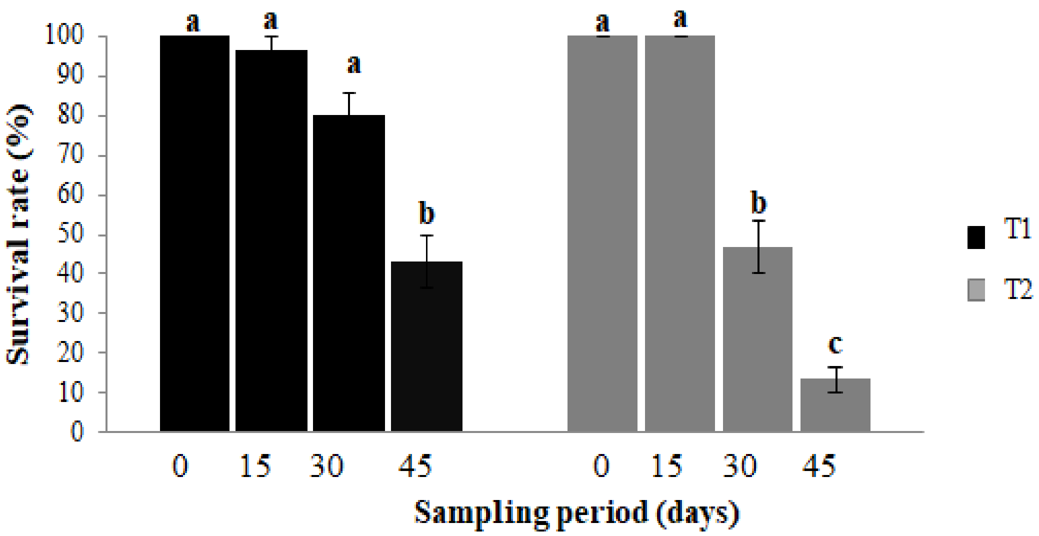

Figure 11. Change in survival rate in every sampling period of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting) cultured in the fixed-off bottom method for 45 days. Bars with different letters are significantly different (p<0.05). Error bars in SEM (standard error of the mean), n= 17-60.

Raft method

The survival rates of T_1 and T_2 did not significantly differ (p<0.05) in every sampling period, as shown in Figure 12. T-test analysis revealed that T_1 did not significantly change (p>0.05) from day 0 to 15, day 15 to 30, and day 30 to 45. However, from day 0 to 30 and day 0 to 45, there was a significantly dropped (p<0.05) in survival rate. T_2 significantly decreased (p<0.05) in survival rate from day 0 to 45 and day 15 to 45 but did not significantly change (p>0.05) from day 0 to 15, day 0 to 30, and day 15 to 30 (Figure 13).

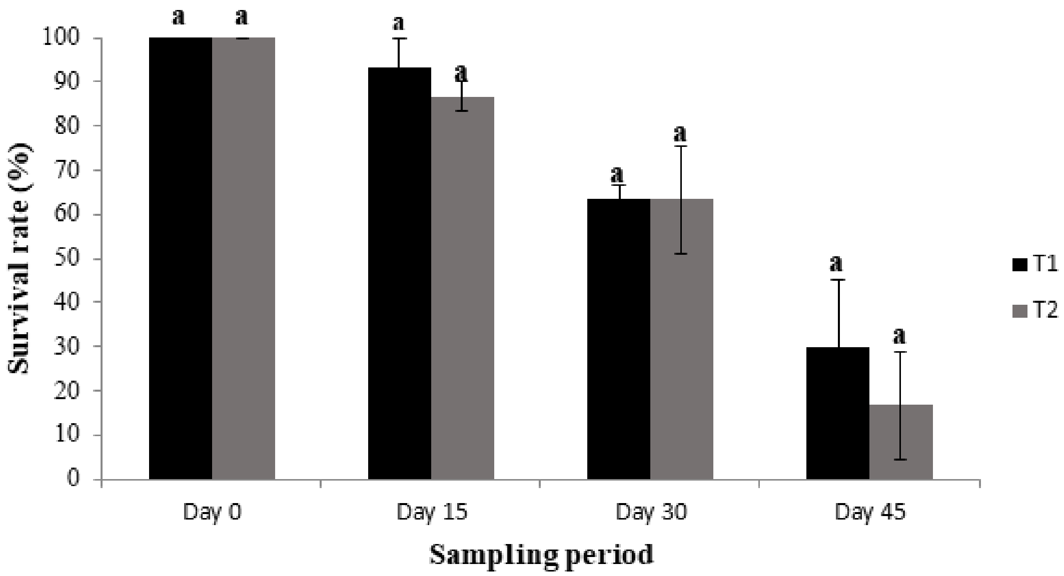

Figure 12. Survival rate of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting) cultured in raft method for 45 days. Bars with same letters are not significantly different (p>0.05). Error bars in SEM (standard error of the mean), n=14-60.

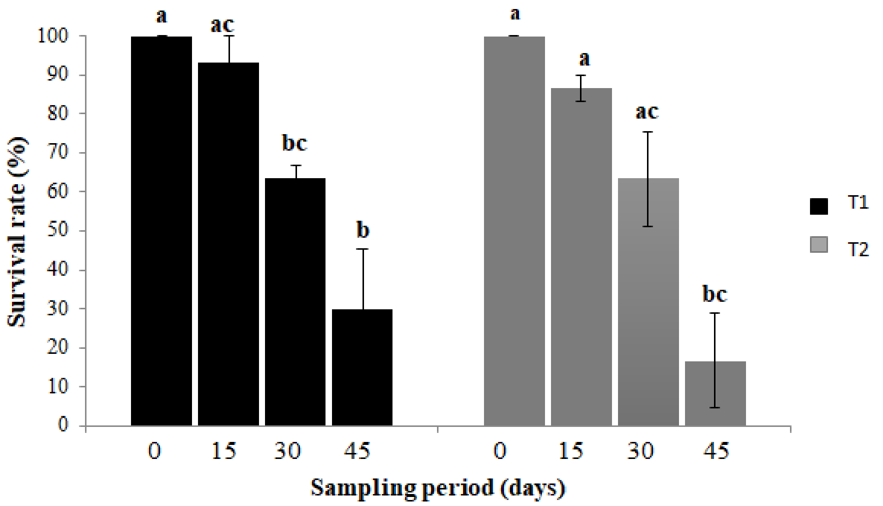

Figure 13. Change in survival rate in every sampling period of *S. cristaefolium* (T_1 = with holdfast, T_2 = vegetative cutting) cultured in raft method for 45 days. Bars with different letters are significantly different ($p<0.05$). Error bars in SEM (standard error of the mean), n=14-60.

Physico-chemical Parameters of Farms

Fixed-off bottom method

Table 1 shows the environmental conditions of *S. cristaefolium* farm using the fixed-off bottom method. The water depth of the farm ranged from 37±1.15 to 132.33±1.45 cm. The salinity ranged from 35.33±0.33 to 35.67±0.33 ‰. The temperature fluctuated throughout the culture period ranging from 34±1.61 to 27±0 ºC, and the pH levels of the farm ranged from 8.34±0 to 8.20±0.01. Water current velocity varied depending on the depth and tides, ranging from 0.008±0 to 0.061±0 m s^{-1}.

Table 1. Physico-chemical parameters of *Sargassum cristaefolium* farmed in the fixed-off bottom method

	Sampling Period						
Parameters	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
Depth (cm)	37±1.15	152±1.00	91.67±2.03	112.33±1.45	123.67±0.88	99.67±0.88	132.33±1.45
Salinity (‰)	35.33±0.33	35.33±0.33	34.67±0.33	34.67±0.33	35.33±0.33	34.67±0.33	35.67±0.33
Temperature (˚C)	34±1.61	29.77±0.98	30.20±0.29	29.23±0.13	28.43±0.03	28.30±0.26	27±0
pH	8.34±0	8.33±0.01	8.49±0.02	8.22±0.04	8.21±0.02	8.10±0.01	8.20±0.01
Current (m s^{-1})	0.008±0	0.02±0	0.021±0	0.098±0	0.084±0	0.045±0	0.061±0

Raft method

The environmental parameters of *S. cristaefolium* farm using the raft method varied every 7 days (Table 2). The water depth of the farm during the culture period was between 103 cm to 204 cm. The salinity fluctuated during the sampling period ranging from 34.33±0.33 to 35±0.58 ‰. The temperature varied during the culture period ranging from 28±0 to 29.50±0.36 ºC. pH levels of the farm site ranged from 7.19±0 to 8.45±0.06. Water current velocity varied depending on the depth and tides, ranging from 0.01±0 to 0.11±0.003 m s^{-1}.

Table 2. Physico-chemical parameters of *Sargassum cristaefolium* farmed in the fixed-off bottom method

	Sampling Period						
Parameters	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
Depth (cm)	103±1.7	170.33±5.17	120.33±2.60	166.6±4.41	173.33±0.88	135.33±0.88	204.33±2.3
Salinity (‰)	34.67±0.33	35±0.58	34.67±0.33	34.67±0.33	34.33±0.33	35±0	34.67±0.33
Temperature (˚C)	29.50±0.36	28.60±0.29	29.40±0.35	28.57±0.12	28.97±0.15	28.33±0.32	28±0
pH	8.33±0.02	7.19±0	8.39±0.03	8.25±0.02	8.45±0.06	8.01±0.03	8.02±0.08
Current (m s^{-1})	0.02±0.004	0.07±0.009	0.01±0	0.11±0.003	0.06±0.002	0.03±0	0.05±0.006

Discussion

Fixed-off Bottom Method

The present study revealed that *S. cristaefolium* cultured in the fixed-off bottom method attained an SGR of -1.51±0.6% day^{-1} and -2.03±0.23% day^{-1} and a final mean weight of 33.89±9.14 g and 20.50±2.18 in T_1 (w/ holdfast) and T_2 (vegetative cutting), respectively. The survival rate of *S. cristaefolium* in both treatments suddenly dropped as the culture period lengthened. The results coincided with the study of Aaron-Amper et al. (2020), where the survival rates of *S. aquifolium* grown using different substrates in the field declined through time. It was also observed by Fortes (1994) that all varieties of brown seaweeds cultured in a fixed-off bottom method generally yielded low growth rates and were greatly affected by season and highly susceptible to grazing pressure and epiphytes. According to Hung et al. (2009), after 60 days of the culture, the brown morphotype *Kappaphycus alvarezii* showed a higher growth rate (3.5-4.6% day^{-1}) from the month of September to February and a lower growth rate (1.6-2.8% day^{-1}) from March to August using fixed-off bottom method. The presence of grazer-like sea urchin (*Tripneustes* sp. and *Strongylocentrotus* sp.) has been observed throughout the sampling period, even though regular maintenance was done. This is maybe the main reason why *S. cristaefolium* cultured in the fixed-off bottom method attained negative SGR and mean weight as well as the survival rate decreased after 45 days in both treatments. Herbivory by sea urchins is known to exert an important influence on kelp forests in temperate water, although effects on microalgae vary depending on the species of sea urchins (Lawrence, 1975). Dworjanyn et al. (2007) investigated the preference of sea urchin (*T. gratilla*) for marine plants with which it co-occurs naturally in New South Wales, Australia displayed a significant preference for the brown alga (*Ecklonia radiate*) used as feeding stimulants. Seaweeds are important components of the coastal ecosystem and serve as food for small crustaceans, fish, grazers, and other herbivores. Grazing fauna prefers tender seaweed species such as *Enteromorpha* sp. and *Sargassum* sp. (Singh, 2017). According to Trono (1992), the plants that are attacked by benthic grazers are easily washed out when the area has a strong water current.

Both treatments (*Sargassum* with holdfast and vegetative cutting) can be used when culturing *S. cristaefolium* using the fixed-off bottom method. According to Norton (1976), *Sargassum* possesses a perennial holdfast that remains on the substrate after the rest of the plant has either been broken off or died away. Thalli of *S. muticum* arising from a small discoid holdfast may reach up to 5 cm total length with few primary lateral branches (Sabour et al., 2013). It is probably because the holdfast, which was in contact with the substratum, fastened the thallus for the attachment strength of each individual. The ability of seaweed to remain fastened in place on the bottom is the crucial performance of the holdfast. The perennial holdfast is responsible for the build-up of one or more main axis with manifold branches to produce branching thallus (Taylor, 1957). According to Silander (1986), vegetative regeneration mainly contributes to local population growth. Other species of *Sargassum*, such as *S. horridum* possess cauline, a structure that is responsible for the growth of primary branches and may also generate a new plant. Reproduction occurs through vegetative fragmentation when pieces of existing plants of *Sargassum* break off to form new branching individuals (Sorcia & Rodrigues, 2011).

Raft Method

The result of *S. cristaefolium* cultured in raft method after 45 days obtained positive SGRs (1.5±0.12% day^{-1} and 1.12±0.40% day^{-1}) and gained a final mean weight that doubled from the initial weight. This was perhaps due to the insusceptibility to grazers like sea urchins and sea stars when cultured in the raft method opposite to the fixed-off bottom method. The raft or longline method provides more space compared to the other methods. Trono (1993) said that this method is opposite to the other method where it makes probably has more advantages and becomes less obstruction against wave action and water current flow. But this water motion or wave can be considered the primary factor in determining productivity. According to Neushul et al. (1992), the rates of nutrient uptake and growth would increase if the marine farm were designed and operated to increase water movement over the plants being grown. This was also observed in the study of Zabala (2005), where the longline method always obtained the highest growth rate and mean weight of red seaweed *Kappaphycus*. *Sargassum* has been already cultured in other places like in Florida, USA, where *S. fluitans* and *S. natans* nutrient-enriched with nitrate and ammonium reached 0.03 to 0.04 doublings day^{-1}. Similarly, when enriched with phosphate, these species obtained growth ranging from 0.05 to 0.08 doublings day^{-1} cultured in a cage and shipboard flowing seawater (Lapointe, 1986). In China, cultured *S. hornerie* in a suspension tank from zygote obtained a length of 5.7 cm, while in tank culture, *S. hornerie* ranged from 1.5 cm to 2.5 cm after 3 months (Pang et al., 2006).

Sargassum with a holdfast and vegetative cutting can be used in the raft method because it obtained the highest SGR, mean weight, and length after 45 days of culture. According to Taylor (1957), the holdfast in *Sargassum*, also called the perennial holdfast, helps give rise to one or more main axes with manifold branches to produce a bushy, branching thallus that can be 20-200 cm or more in length. It also helps the *Sargassum* from the strong wave motion. Most of the brown seaweeds depend on their survival from the holdfast. The holdfast performance is crucial to the ability of the seaweeds to remain fastened on the bottom (Kawamata, 2001). According to Silander (1986), vegetative regeneration can mainly contribute to local population growth. Some of the *Sargassum* species possess a cauline structure that is responsible for the growth of some primary branches and may also be the reason that a plant can generate a new structure (Sorcia & Rodriguez, 2011). In the study of Moreira and Suárez (2002), vegetative fragmentation causes reproduction when pieces of the existing plant break off, forming a new branching individual.

The survival rate of *S. cristaefolium* cultured in the raft method decreased after 45 days in both *Sargassum* with a holdfast and vegetative cutting. The probable reason could be due to the garbage and other waste materials that flowed through the farm and got trapped. These may block the sunlight and may hinder photosynthesis. Grazers like herbivorous fish (*Siganus* spp.) also affect the survival of the *Sargassum*, which was present during the culture period. Grazing adversely affects the production in the *Kappaphycus* seaweed farm (Romero, 2002).

Conclusion

In conclusion, both types of *S. cristaefolium* seedlings (with holdfast and vegetative cutting) can be used for cultivation in raft method. However, both seedlings attained a negative SGR in the fixed-off bottom but gained a positive SGR in the raft method. A continuous decline through time in survival rates for both seedlings and methods was also observed due to grazers and floating wastes, respectively. This study would serve as preliminary information on the cultivation of *Sargassum* in Tawi-Tawi, southern Philippines.

Conflict of Interest

The authors declare that they have no conflict of interest.

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