第 48 卷 第 7 期
2021 年 7 月

湖南大学学报（自然科学版）
Journal of Hunan University（Natural Sciences）

Vol. 48. No. 7.
July 2021

Open Access Article

# Effect of Different Substrates on Growth and Protein Content of *Caulerpa Racemosa*

**Seto Windarto*, Angga Hendra Prastiwahyudi, Titik Susilowati, Alfabetian H. Condro Haditomo, Dicky Harwanto**

Department of Aquaculture, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Semarang, Indonesia

**Abstract:** *Caulerpa racemosa* is a green seaweed commonly found in several locations in the Indo-Pacific ocean, including along the coast of Indonesia, especially in Jepara, Central Java. This study aims to determine the best type of substrate to increase the growth of *C. racemosa* and its protein content. Utilizing the suitable substrate is expected to increase the growth, production, quality improvement, and protein content of *C. racemosa*. Research on the substrate on the growth and protein content of *C. racemosa* from Jepara has never been carried out. The treatments used in this research were: A (bamboo woven); B (coral fragments); C (sandy mud); and D (net). Data collected included Absolute Growth, Specific Growth Rate (SGR), the protein content of *C. racemosa*, and the water quality of the media. Results showed that the values of absolute growth and SGR in each treatment from highest to lowest were C (0.58 ± 0.14), B (0.53 ± 0.14), D (0, 32 ± 0.14), and A (0.24 ± 0.05); SGR were C (3.94 ± 0.60% / day), B (3.77 ± 0.61% / day), D (2.57 ± 1.14% / day) and A (2.05 ± 0.28% / day). The difference in the type of substrate gives a significant effect (P <0.05) on *C. racemosa*. The type of sandy mud substrate is the best substrate in this study for *C. racemosa* growth (absolute growth rate values of 0.58 ± 0.14 g and SGR values of 3.94 ± 0.60% / day). On the other hand, the bamboo woven substrate was observed the best for *C. racemosa* protein content (5.87%). The water quality in maintenance media is in a feasible range for the maintenance of *C. racemosa*.

**Keywords:** seagrapes, nutrition, sandy mud, growth, bamboo.

# 不同基质对总状花椰菜生长及蛋白质含量的影响

**摘要:** 总状花椰菜是一种绿色海藻，常见于印度洋-太平洋的多个地点，包括印度尼西亚沿海，尤其是中爪哇的杰帕拉。本研究旨在确定促进总状花椰菜生长及其蛋白质含量的最佳底物类型。利用合适的底物有望增加总状花椰菜的生长、产量、质量改进和蛋白质含量。对来自杰帕拉的总状花椰菜的生长和蛋白质含量的底物的研究从未进行过。本研究中使用的处理方法是：一种（竹编）；乙（珊瑚碎片）；C（砂泥）；和D（净）。收集的数据包括绝对生长、比生长率、总状花椰菜的蛋白质含量和培养基的水质。结果表明，各处理的绝对生长和比生长率从高到低依次为C（0.58±0.14）、乙（0.53±0.14）、D（0、32±0.14）和一种（0.24±0.05）;比增长率分别为C（3.94±0.60%/天）、乙（3.77±0.61%/天）、D（2.57±1.14%/天）和一种（2.05±0.28%/天）。底物类型的差异对总状花椰菜有显着影响（磷<0.05）。砂质泥基质类型是本研究中总状花椰菜生长的最佳基质（绝对生长速率值为0.58±0.14g，比生长速率值为3.94±0.60%/天）。另一方面，竹编织基材的总状花椰菜蛋白质含量最高（5.87%）。维护介质中的水质在维护总状花椰菜的可行范围内。

**关键词：**海葡萄，营养，沙泥，生长，竹子。

Received: April 18, 2021 / Revised: May 15, 2021 / Accepted: June 13, 2021 / Published: July 31, 2021

About the authors: Seto Windarto, Angga Hendra Prastiwahyudi, Titik Susilowati, Alfabetian H. Condro Haditomo, Dicky Harwanto, Department of Aquaculture, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Semarang, Indonesia

Corresponding author Seto Windarto, seto.windarto@live.undip.ac.id

# 1. Introduction

*Caulerpa racemosa* is a green seaweed commonly found in several locations in the Indo-Pacific Ocean, including along the coast of Indonesia. Initially, *C. racemosa* was discovered on the Red Sea coast [1]. This species is one of the seaweeds that can be used as food. Tastes of *C. racemosa* like the taste of Caviar fish eggs, so it is known as "green caviar." In addition, because the shape is similar to grapes, *C. racemosa* is also known as "sea grape." As a food material, *C. racemosa* provides many benefits. These species are a source of minerals such as calcium, potassium, magnesium, sodium, copper, iron, zinc, vitamin E, and peptides [2, 3] and several types of essential, low-fat amino acids polyunsaturated fatty acids [4, 5]. *C. racemosa* can ward off free radicals because this type of algae contains folic acid, thiamine, and ascorbic acid. *Caulerpa* sp. also contains caulerpenyne, which shows bioactivity to human cell lines and has anticancer, antitumor, and antiproliferation properties [5].

During this time, international demand for seaweed continues to increase but is still dominant in the group Eucheuma/Kappaphycus and *Gracilaria* sp., While in the Chlorophyceae class Caulerpa, it is still only utilized and traded locally [6]. *C. racemosa*'s high demand in the international market occurs in the territory of Japan [7]. In Indonesia, especially on Java, this species is commonly found in Jepara, Central Java, and local people know it as "Latoh."

The availability of *C. racemosa* is still very lacking because it still relies on wild products. The *C. racemosa* is still rarely cultured. If there is culture, the technology is still not optimal. In Indonesia, the culture technique of *C. racemosa* is done by immersing it in a soil substrate such as a system of planting rice in the area/land of the former pond. The *C. racemosa* is phytobenthos, where algae live on the seabed substrate, such as dead coral, coral fragments, sand, and mud [8]. The distribution of marine algae *C. racemosa* and its density in water depends on the type of substrate, season, and species composition [9].

Culture with the right technology is required To fulfill the increasing market demand. A critical factor in the culture of *C. racemosa* is the determination of the substrate. The various types of substrates have different characters, which undoubtedly influence the growth of *C. racemosa*.

Research on the substrate in *C. racemosa* has been done by Tanduyan [10]. This research was conducted in Cebu, Philippines. The substrate used was mud, sand, and rock with off-bottom culture in the waters of San Francisco, Cebu, Philippines. Dahlia [11] also studied substrate on *C. racemosa*, sandy mud, and dead coral fragments. The study was conducted at the Jepara Coastal Development Laboratory (LPWP), Central Java. Information about the ideal substrate for *C. racemosa* is still needed, especially for local farmers. Research on the growth substrates and protein content of *C. racemosa* from Jepara is still rarely done. The difference in the substrate used is thought to affect the growth and protein content of *C. racemosa*. Therefore, this research needs to be carried out to determine the type of substrate that is most suitable for optimal growth of *C. racemosa* originating from the waters of Jepara, Indonesia.

# 2. Materials and Methods

## 2.1. Materials

This research was conducted at the Central Office of Brackish Aquaculture Fisheries (BBPBAP) Jepara. The seaweed used was from the *Caulerpa racemosa* species or commonly known as sea grape. The seed of *C. racemosa*, which was around 30 days old, originating from the natural waters of Jepara. The Pond Culture used was a two-meter diameter round tarpaulin pond with a one-meter pond height. This tarpaulin pond was used an iron frame and had no outlets. This study was used several types of substrates as a place of attachment for *C. racemosa*, i.e., bamboo, coral fragments, sandy mud, and net.

The treatments were Treatment A (Culturing *C. racemosa* on a bamboo woven substrate), Treatment B (Culturing *C. racemosa* on coral fragments), Treatment C (Culturing *C. racemosa* on sandy mud substrate, and Treatment D (Culturing *C. racemosa* on the net substrate).

Choosing bamboo woven substrate was based on Yudasmara [12], *C. racemosa* can grow optimally with the final growth result reaching twice the initial weight. The selection of coral fragments and sandy mud substrate based on *C. racemosa*'s natural habitat as revealed by Atmadja [13], which *C. racemosa* is phytobenthos, and its growth is epiphytic. In comparison, net (traditional rectangular cage) substrate was chosen because local farmers widely use this substrate for seaweed culture, other than *C. racemosa*.

## 2.2. Preparation and Culture of *C. Racemosa*

The study began with the preparation of a culture pond. The culture pond used an iron tarpaulin pond. The water had filled the pond up to a height of 80 cm. After the pond was filled, the substrate was placed at the bottom of the pond.

The substrate used was woven bamboo, coral fragments, sandy mud, and net. All of these substrates had been washed to be clean. The prepared substrates were then put into each wooden box, measuring 50 x 50 x 10 cm. The substrate was placed at the bottom of the pool and then given a ballast not to change its position. The arrangement between the substrate boxes was spaced to avoid contact between the media when *C. racemosa* growth.

The final step taken in the preparation of the pond was the application of fertilizers using nitrates and phosphates in a ratio of 8: 1 to the culture media as *C. racemosa* nutrition. It gave a higher N value than P because the N element is a limiting factor in the growth of these aquatic organisms in saline waters. Fertilization used $NaNO_3$ and $KH_2PO_4$, weighed of 0.068 and 0.0136 g / L seawater. The material was diluted using distilled water with a ratio of 1 mL distilled water equal to 1 L of seawater in the pond, where the pond had a volume of ± 2500 L. Fertilizer, that has been diluted with distilled water, was then put into the pond.

After the ponds and the system were ready to use, 250 g of *C. racemosa* seed was planted on each substrate by clamping using small bamboo slits so that their position did not change on each substrate.

### 2.3. Absolute Growth

Absolute growth calculation was calculated based on Hasbullah [13]:

$$W = W_t - W_o$$

where:
W = absolute growth (g)
$W_o$ = weight at the start of culture (g)
$W_t$ = weight at the end of culture (g)

### 2.4. Specific Growth Rate

SGR value was calculated based on the Effendi [13]:

$$SGR = ((\text{Ln } W_t - \text{Ln } W_0)/t)) \times 100\%$$

where:
SGR = Specific growth rate (% / day)
$W_t$ = weight at the end of the culture (g)
$W_0$ = weight at the beginning of the culture (g)
t = Length of culture (days)

### 2.5. Protein Analysis

Protein analysis was carried out using Kjeldahl methods at the Central Java Agricultural Technology Development Center. This analysis was carried out twice, at the beginning and end of the study.

### 2.6. Water Quality

Water quality measurement, i.e., DO, temperature, pH, and salinity, was done every day (08.00) and evening (16.00). The DO, temperature, and pH were measured by a water quality checker (YSI 550A), while a refractometer measured salinity.

## 3. Result

Based on the weight measurements carried out at the beginning and end of the study for 30 days, unlimited weight growth data were obtained on *C. racemosa* (Table 1). The values of absolute weight growth in each treatment from highest to lowest were C (0.58 ± 0.14), B (0.53 ± 0.14), D (0, 32 ± 0.14), and A (0.24 ± 0.05). The SGR values of *C. racemosa* at each treatment also can be seen in Table 1. As same as absolute weight growth, the SGR values for each treatment from highest to lowest were treatment C (3.94 ± 0.60% / day), B (3.77 ± 0.61% / day), D (2.57 ± 1.14% / day) and A (2.05 ± 0.28% / day).

Table 1 Absolute growth and specific growth rate of *C. racemosa* during the study (numbers with different superscript letters in the same row indicate a significant difference of P<0.05)

| Variable | Treatment (Mean±SD) | | | |
|---|---|---|---|---|
| | **A** | **B** | **C** | **D** |
| Absolute Growth Rate (g) | $0.24{\pm}0.05^a$ | $0.53{\pm}0.14^b$ | $0.58{\pm}0.14^b$ | $0.32{\pm}0.14^{ab}$ |
| Specific Growth rate ($\%.d^{-1}$) | $2.05{\pm}0.28^a$ | $3.77{\pm}0.61^c$ | $3.94{\pm}0.60^c$ | $2.57{\pm}1.14^{ab}$ |

The results of protein analysis that have been carried out observed that the highest content of *C. racemosa* protein was shown in the treatment of bamboo woven substrates with a value of 5.87% (Table 2). There was a decrease in the value of the protein content of *C. racemosa* on each substrate used.

Table 2 Protein analysis results of *C. racemosa*

| No. | Treatment (Substrate) | Protein content (%) | |
|---|---|---|---|
| | | **Start** | **End** |
| 1. | A (bamboo woven) | 7.20 | 5.87 |
| 2. | B (coral fragments) | 7.20 | 5.14 |
| 3. | C (sandy mud) | 7.20 | 5.13 |
| 4. | D (Net net) | 7.20 | 4.39 |

In general, all ponds' water quality showed that the values were still suitable for *C. racemosa* culture. The results of water quality during the study can be seen in Table 3.

Table 3 Water quality

| Parameter | Unit | Range | Suitable values |
|---|---|---|---|
| DO | mg/l | 3.02 – 9,12 | > 5,0 mg/l [14] |
| pH | | 8,16 – 9,12 | 6,8 – 9,6 [15] |
| Temperature | $^oC$ | 26,6 – 32,2 | 20 – 31 [16] |
| Salinity | mg/l | 34 – 42 | 5—35 [17] |

## 4. Discussion

### 4.1. Absolute Growth of *C. Racemosa*

Research on the effect of using different substrates on the growth and protein content of *Caulerpa racemosa* in Jepara has never been done, so this research is expected to provide information to increase the production and nutritional content of *C. racemosa*. Based on the study results, it was shown that the different substrates used affected the growth and protein content of *C. racemosa*.

Based on the analysis of variance that has been done, the difference in substrate gives a significant effect ($p < 0.05$) on the growth of absolute weight of *C. racemosa*. The results showed that treatments B (coral fragments) and C (sandy mud) were not significantly different but significantly different from treatments A (woven bamboo) and D (net). Treatment B's absolute weight growth value was 0.53 ± 0.14 g, and treatment C was 0.58 ± 0.14. Both of these treatments had the best absolute weight growth value. Still, when viewed from its material availability and legality, sandy mud substrate is considered better than coral fragments. That is because the number of dead coral substrates is limited to the shoreline. Using coral in the bottom waters will violate the regulation of Indonesia's minister of fisheries and marine affairs. According to the Regulation of the Minister of Marine Affairs and Fisheries [19], the protection of coral reefs is not to disturb their habitat. Thus, the use of sandy mud substrate is the best option.

The absolute weight growth value of *C. racemosa*, which was planted with different substrates, got the highest value in the treatment with sandy mud substrate (treatment C), which was 0.58 ± 0.14g. The lowest was in the treatment with the bamboo woven substrate (treatment A), which was 0.24 ± 0.05 g. High absolute growth value on sandy mud substrate due to *C. racemosa* could utilize the content in the media through its roots. The roots of *C. racemosa* attached to the substrate also function to absorb the nutrients needed for growth. Malta [20] reported that algae also had a high ability to absorb nutrients from sediments through the roots. *C. racemosa* depends on the availability of nutrients, especially nutrients in nitrogen (N), for the growth process and photosynthesis. According to Roleda [21], an essential nutrient requirement of seaweed is nitrogen.

Absolute weight growth in the treatment media C (sandy mud) was also caused by the nutrient content higher in sandy mud than in other media. Ain [16] stated that the seaweed life in water is determined by the environment and water substrate, where the substrate is a place to attach seaweed or algae. The difference in the substrate in the waters will affect the density of seaweed. *C. racemosa* can grow optimally by absorbing nutrients present in the media as its energy source. The nutrient is an element needed by plants as a source of energy used to arrange various cell components during growth and development.

*C. racemosa* on sandy mud substrate got nutrients from the waters and the substrate, sandy mud itself. According to Xiao [22], seaweed in its metabolic process requires water physical and chemical factors such as water movement, temperature, salinity, nutrients (such as nitrates and phosphates), and solar lighting. Masyahoro and Mappiratu [23] explained that the main nutrient content needed by seaweed, such as nitrate and phosphate, is very influential on its reproductive stage. When both nutrients are available, the fertility of seaweed increases rapidly. The elements N and P are nutrients that are needed by algae in their growth. The P elements, which are few and compared with the incompatible N elements, are often a limiting factor for algal growth [24]. According to Alamsjah [25], an increase in growth indicates that the growth of seaweed has entered the stage of cell extension due to the availability of nutrients sufficient for growth.

### 4.2. Specific Growth Rate of *C. Racemosa*

Based on the analysis, the substrate's difference has a significant effect ($p < 0.05$) on the *C. racemosa* SGR. Similar to the absolute growth value, the SGR value of *C. racemosa* was planted with sandy mud substrate (treatment C). was the highest. It was possible because the nutrients possessed by sandy mud were higher than the substrate in other treatments to be absorbed and used by *C. racemosa* to grow. According to Berame [26] and Romano [27], Caulerpa is an epibenthic plant that attaches to the mud substrate at the bottom of the water. Sandy sludge substrates generally have higher availability of N and P nutrients. The availability of N and P nutrients in the substrate is related to particle size and sediment thickness. The smaller the sediment size, the greater the N and P nutrients in the substrate [28].

The *C. racemosa* is very dependent on the availability of nutrients, especially nutrients in the form of nitrogen (N), for the growth process and in the process of photosynthesis. According to Roleda [20], the essential nutrient requirement of seaweed is nitrogen. Nitrogen is a macro element that is useful for stimulating the growth of a plant so that it can develop rapidly. Lack of element N will inhibit the growth of seaweed because it is an element used in photosynthesis. However, excessive nitrogen levels are also not suitable for *C. racemosa*. Therefore, they need the right nitrogen concentration according to their needs. Higher nitrogen concentration causes the seaweed to become weak and cause the thallus to break easily so that its growth will be inhibited. It affects the biomass, which in turn will affect the daily growth rate. According to Luning [29], the range of nitrates that support the life of seaweed is 0.0166 - 83.333 μM. According to Effendi [30], a good phosphate concentration value is 0.05-1.78 ppm, while the Directorate General of Aquaculture [31] states that a good phosphate value for seaweed growth ranges from 0.09 to 1.80 ppm.

The SGR value of *C. racemosa* in treatments B and C, i.e., 3.77 ± 0.61 and 3.94 ± 0.60% / day, respectively, were classified as good. It is consistent with the study of Kawaroe [32], who reported that SGR of good seaweed was 3–5% per day. Meanwhile, the value of SGR *C. racemosa* in treatments A and D, although less than 3% per day, but still, more than 2% per day, was quite good. It is based on Syahlun [33], which states that a seaweed farming activity is beneficial if it has a minimum SGR value of 2% per day. Furthermore, Silea and Mashita [34] stated that if the growth rate of seaweed reaches 3% / day, then harvesting can be done faster, which is about 25 days.

The SGR value varies from this study, possibly due to the number of nutrients received by *C. racemosa*. Bamboo and net woven substrates were not able to contribute to providing nutrients for *C. racemosa*. Therefore, the supply of nutrients depends only on the nutrients present in the waters. That was different from the substrate of dead coral fragments and muddy sand, which provided additional nutrition for *C. racemosa*. According to Sangkia [35], seaweed production results are influenced by internal and external factors. Internal factors are the type and quality of seaweed used, while external factors are the physical and chemical environmental conditions of the waters that affect the growth rate of seaweed.

The SGR value of *C. racemosa* on this sandy mud substrate was higher than the research conducted by Danesa [36], where the study has an SGR value of 3.85% per day. That might be caused by differences in the substrate and depth used. The previous study used a plastic tray substrate at a depth of 1.2 m in open water. The use of plastic trays causes *C. racemosa* to only rely on the absorption of nutrients present in the waters. The depth used was too deep compared to the depth applied in the present study. That causes photosynthesis carried out by *C. racemosa* less than the maximum. According to Darmawati [37], at a depth of 50 cm, seaweed can utilize sunlight more optimally as an energy source for photosynthesis and help seaweed obtain nutrients or nutrients. Increased photosynthesis can increase the ability of seaweed to obtain nutrients or nutrients. The brightness of the seawater influences the amount of sunlight absorbed. Therefore, the need for sunlight is available in optimal amounts, the depth in cultivating seaweed must be arranged. In addition, the low growth rate of seaweed, with increasing depth, was also caused by low oxygen circulation.

### 4.3. Protein Content of *C. Racemosa*

The protein content of *C. racemosa* samples at the beginning of the study was 7.20%. However, after going through the study period, protein values in all treatments were decreased. It is assumed that nutrient needs were not maximally fulfilled for *C. racemosa* because nutrients can only be used for growth alone, not increasing protein content. According to Pradhika [1], seaweed increases because seaweed gets additional N elements derived from solid and liquid fertilizers. N will be absorbed by seaweed to compile the protein needed to form the protein seaweed cells.

Furthermore, the protein value in *C. racemosa* decreased compared to the beginning of the study, presumably due to the lack of element N to carry out the synthesis process into protein. According to Ladyba [38], protein in plants or algae requires N to be synthesized. The element N in fertilizer will affect the amount of protein produced by algae. That is because plants will absorb the N elements as constituents of amino acids. Plants in the form of Nitrates absorb the N elements. Then nitrate is reduced to amino acids ($NH_2$) by the enzyme nitrate reductase, which requires cellular energy metabolic activity. Ammonium assimilation is swift, forming organic N compounds, glutamic acid. Amino acids can then be arranged into plant proteins in the ribosome.

The value of *C. racemosa* protein on coral fragments and sandy mud substrate had a lower value than the value of *C. racemosa* protein on bamboo woven media. It was inversely proportional to the higher growth results in the media of coral fragments and sandy mud than bamboo-woven media. The high protein value in woven bamboo could be caused by *C. racemosa* on the substrate, which tends to be lower because *C. racemosa* did not grow as much as in the media of coral fragments and sandy mud. This lower density leads to less competition in the absorption of nutrients and a more optimal photosynthesis process. The protein content of *C. racemosa* is obtained from the N elements present in the water and the photosynthesis process. According to Nasmia et al. [39], nutrients in the waters, especially nitrogen availability, affect seaweed's growth and protein content.

Furthermore, Claire [40] explained that plant spacing affects water traffic that carries nutrients for the nutritional needs of *Caulerpa* sp. In addition, plant spacing will affect the area of seaweed thallus exposed to sunlight to affect the photosynthesis process indirectly. Yuan [41] mentions that seaweed, as an organism that carries out photosynthesis, its chemical composition is influenced not only by the concentration of aquatic nutrients but also by the depth of the waters.

The value of *C. racemosa* protein content in the net substrate is the lowest. It could be caused by the net being an inorganic/synthesis material. Therefore, there is no nutrient content in it that *C. racemosa* can absorb. According to Soelistiyowati [42], nitrate is positively correlated with thallus diameter, and phosphate content is positively correlated with branching index. The roots of *C. racemosa* attached to the substrate also function to absorb the nutrients needed for growth [20].

### 4.4. Water Quality

Based on the results of water quality measurements, it was obtained that the value of water quality still met the feasibility of *C. racemosa* culture. The result of temperature measurements during the study was ranged from 26.6 to 32.2 °C. The temperature during the study was still relatively optimal for the life of *C. racemosa*. Following Piazzi [43], the optimal temperature range to support *C. racemosa* growth ranges from 25–31°C.

Environmental temperature plays a vital role in photosynthesis, where the higher the intensity of the sun and the optimum temperature conditions, the more systematic the results of photosynthesis. Water temperature also affects several physiological functions of seaweed, such as photosynthesis, respiration, metabolism, growth, and reproduction.

Dissolved oxygen measured during the study showed results in the range of 3.02 - 9.12 mg / L. The

DO values were still within the limits of eligibility for *C. racemosa* culture. According to Mamang [15], the DO quality standard for seaweed is more than 5 mg / l. It means that if the dissolved oxygen in the waters reaches 5 mg / l or more, then the metabolism of seaweed can run optimally. The values of DO in *C. racemosa* culture ponds indicate values above the maximum oxygen saturation in salinity waters. The highest DO value was 9.12 mg / L in the pond with a salinity of 35 ppt and a temperature of 30°C. The maximum oxygen saturation that the waters can accommodate under the same conditions is 6.236 mg / L [44]. Oxygen saturation of more than 100% can occur because no biota uses the water DO and plants that carry out photosynthesis.

Furthermore, Fondriest [44] states that 100% oxygen saturation is the balance point for gases in water. However, several factors can influence this. Aquatic respiration and decomposition reduce DO concentrations, while rapid aeration and photosynthesis can contribute to saturation. During the process of photosynthesis, oxygen is produced as a waste product. That is what increases DO concentration, which has the potential to bring it above 100% saturation.

The pH value obtained at the time of the study was 8.16 - 9.12. The results of these variables were still within the limits of tolerance. According to Ilustrisimo [45], *C. lentillifera* normally developed at pH 8 and showed an increase in biomass at pH values ranging from 7.7 to 8.3. Mamang [15] and Ain [16] supported this, which stated that almost all algae like the pH range 6.8 - 9.6.

Salinity values obtained at the time of the study ranged between 33-35 ppt. The results of these variables were also still within the tolerance limits for *C. racemosa*'s life. Dawes [18] reported that macroalgae can still live on salinity between 5 - 35 ppt. Furthermore, according to Perry [46], sublittoral algae can tolerate salinity 0.5 - 1.5 times that of average salinity (16 - 50 ppt), while intertidal algae can live in the range of salinity of 0.1 - 3.5 times average salinity. The salinity value of 35 in *C. racemosa* culture produces a maximum growth rate. According to Guo [3], *C. lentillifera* seaweed survives at the salinity of 20 - 50 ‰, but growth can only occur at 20 - 45 ‰. The maximum specific growth rate of 2.038 ± 0.465% / day occurs at a salinity of 35 ‰. According to the research of Murillo [47], Caulerpa will have optimal growth in the 20-30 ppt salinity range. This growth occurred in terms of biomass growth and stolon length. Caulerpa growth at 35 ppt salinity was less than the maximum growth of biomass, but the growth of stolon length was still quite good, where the yield was slightly below the growth of Caulerpa stolon at 30 ppt salinity, which was the best growth.

## 5. Conclusion

Research on the effect of using different substrates on the growth and protein content of *Caulerpa racemosa* in Jepara has never been done, so this research is expected to provide information to increase the production and nutritional content of *C. racemosa*. The difference in the type of substrate gives a significant influence (P <0.05) on the growth of *C. racemosa*. The type of sandy mud substrate is the best substrate in this study for *C. racemosa* growth (absolute growth rate values of 0.58 ± 0.14 g and SGR values of 3.94 ± 0.60% / day). On the other hand, the bamboo woven substrate was observed the best for *C. racemosa* protein content (5.87%).

## References


[1] PRADHIKA V. D, SURYONO, and SEDJATI S. Effect of Addition of Solid and Liquid Fertilizer on Growth, Total Chlorophyll and Protein Content *Caulerpa racemosa*, J.Agardh, 1873 (Ulvophyceae: Caulerpaceae). *Journal of Marine Research*, 2019, 8 (3): 269-276. https://doi.org/10.14710/jmr.v8i3.25269

[2] MAGDUGO R. P, TERME N., LANG M., PLIEGO-CORTÉS H., MARTY C., HURTADO A. Q., BEDOUX G. and BOURGOUGNON N. An Analysis of the Nutritional and Health Values of *Caulerpa racemosa* (Forsskål) and *Ulva fasciata* (Delile) - Two Chlorophyta Collected from the Philippines. *Molecules*, 2020, 25(12): 2901. https://doi.org/10.3390/molecules25122901

[3] BLEAKLEY S., & HAYES M. Algal Proteins: Extraction, Application, and Challenges Concerning Production. *Foods*, 2017, 6(5): 33. https://doi.org/10.3390/foods6050033

[4] QUDUS B. A. A, ABDUL R. S., PALANIVELOO K., NAGAPPAN T, SURAIZA N. R. N., WEE J. G., CHELLAPPAN D. K., CHELLIAN J., and KUNNATH A. P. Bioprospecting Cultivated Tropical Green Algae, *Caulerpa racemosa* (Forsskal) J. Agardh: A Perspective on Nutritional Properties, Antioxidative Capacity and Anti-Diabetic Potential. *Foods*, 2020, 9(9): 1313. https://doi.org/10.3390/foods9091313

[5] GAILLANDE DE C., PAYRI C., REMOISSENET G., and ZUBIA M. Caulerpa consumption, nutritional value, and farming in the Indo-Pacific region. *Journal of Applied Phycology*, 2017, 29: 2249–2266. https://doi.org/10.1007/s10811-016-0912-6

[6] Seaweed Industry Association of the Philippines. https://siap-seaweed.tripod.com/

[7] TAPOTUBUN A. M., THEODORA E., RIRY J., TAPOTUBUN E. J., FRANSINA E. G., MAILOA M. N., RIRY W. A., SETHA B., and RIEUWPASSA F. Seaweed *Caulerpa* sp position as functional food. *Institute of Physics Conference Series: Earth and Environmental Science*, 2020, 517: 1-8. https://doi.org/10.1088/1755-1315/517/1/012021

[8] BOUMEDIENE H. K., & LOTFI B. T. First Record of Invasive Green Algae *Caulerpa racemose* var. *cylindracea* in Oran Bay (western Alegria). *Indian Journal of Geo-Marine Sciences*, 2019, 48(3): 335-342. http://aquaticcommons.org/26639/

[9] SUPRIADI, SYAMSUDDIN R., ABUSTANG A., and YASIR I. The Growth and Carotenoid Content of Lawi-Lawi *Caulerpa racemosa* Grown in Different Substrates. *Jurnal Rumput Laut Indonesia*, 2016, 1(2): 117-122.

https://journal.indoseaweedconsortium.or.id/index.php/jrli/article/view/28
[10] TANDUYAN S. N., GONZAGA R. B., and BENSIG V. D. Off bottom culture of *Caulerpa lentillifera* in three different water levels in the marine waters of San Francisco, Cebu, Philippines. Galaxea. *Journal of Coral Reef Studies (Special Issue)*, 2013: 123-132. https://doi.org/10.3755/GALAXEA.15.123
[11] DAHLIA I., REJEKI S., and SUSILOWATI T. Effect of Different Fertilizer and Substrate Doses on the Growth of Caulerpa lentillifera. *Journal of Aquaculture Management and Technology*, 2015, 4(4): 28-34. https://ejournal3.undip.ac.id/index.php/jamt/article/view/9802
[12] YUDASMARA G. A. Cultivation of Sea Grape (*Caulerpa racemosa*) through Bamboo Rigid Quadrant Nets Substrate. Department of Marine Cultivation. *Universitas Pendidikan Ganesha, Singaraja-Bali*, 2014, 3(2): 468–473. http://dx.doi.org/10.23887/jst-undiksha.v3i2.4481
[13] HASBULLAH D., AKMAL, BAHRI S., AGUNG I. G. P., SUAIB M., and ILHAM I. Implementation of Various Types of Basic Substrates as Production Media of Lawi-Lawi Caulerpa sp. *Octopus Jurnal Ilmu Perikanan*, 2014, 3(1): 244-251. https://journal.unismuh.ac.id/index.php/octopus/article/view/543
[14] EFFENDI I. *Fisheries Biology*. Yogyakarta: Yayasan Pustaka Nusantara, 1997.
[15] MAMANG N. *Seedling Growth Rate of Eucheuma cottoni with Thallus Origin Treatment on Seed Weight in Lakeba Waters, Bau-Bau City, Southeast Sulawesi*. Bogor: Fakultas Perikanan dan Ilmu Kelautan Institut Pertanian Bogor, 2008.
[16] AIN N., RUSWAHYUNI, and WIDYORINI N. Relationship between Seaweed Density and Different Bottom Substrate in Bandengan Coastal, Jepara. *Diponegoro Journal of Maquares*, 2014, 3(1): 99-107. https://ejournal3.undip.ac.id/index.php/maquares/article/view/4426
[17] ALAM A. *Quality of Seaweed Carrageenan Eucheuma spinosum in the waters of Punaga Village, Takalar Regency*. Makassar: Fakultas Ilmu Kelautan dan Perairan, Universitas Hasamuddin, 2011.
[18] DAWES C. J. The Biology of Commercial Important Tropical Marine Algae on Bird. In *Seaweed Cultivation For Renewable Resources*. Amsterdam, Elsevier, 1987.
[19] MINISTRY OF MARINE AFFAIRS AND FISHERIES. *Zoning Plan for Specific National Strategic Areas for All Islands in the Riau Islands Province 2018-2037 Nomor 41*. Ministry of Marine Affairs and Fisheries, 2018.
[20] MALTA E., GABRIEL D., and VERGARA J. Nitrogen Load and Irradiance Affect Morphology, Photosynthesis and Growth of *Caulerpa prolifera* (Bryopsidales: Chlorophyta). *Journal of Marine Ecology Progress Series*, 2005, 298: 101-114. https://doi.org/10.3354/meps298101
[21] ROLEDA M. Y., & HURD C. L. Seaweed nutrient physiology: application of concepts to aquaculture and bioremediation. *Phycologia*, 2019, 58(5): 552-562. https://doi.org/10.1080/00318884.2019.1622920
[22] XIAO X., AGUSTI S., LIN F., XU C., YU Y., PAN Y., LI K., WU J., and DUARTE C. M. Resource (Light and Nitrogen) and Density-Dependence of Seaweed Growth. *Frontiers in Marine Science*, 2019, 16: 618. https://doi.org/10.3389/fmars.2019.00618
[23] MASYAHORO, & MAPPIRATU. Growth Response at Various Seed Depths and Harvest Time of Seaweed *Eucheuma cottonii* in Palu Bay. *Media Litbang Sulteng*, 2010, 3(2): 104-111. http://jurnal.untad.ac.id/jurnal/index.php/MLS/article/view/78/71
[24] HUTABARAT S. *Aquatic Productivity and Plankton Study on Fisheries and Marine Science*. Semarang, Badan Penerbit Universitas Diponegoro, 2000.
[25] ALAMSJAH M. A., TJAHJANINGSIH W., and PRATIWI A. W. The effect of the combination of NPK and TSP fertilizers on growth, moisture content and chlorophyll-a Gracilaria verrucose. *Jurnal Ilmiah Perikanan dan Kelautan*, 2009, 1(1): 103-116. http://dx.doi.org/10.20473/jipk.v1i1.11705
[26] BERAME. *Owner Berame's lato farm*. Kalawisan, 2003.
[27] ROMANO S. Culture of "Lato"(*Caulerpa lentillefera*) in ponds using artificial substrates. *The Fishers Journal of Colleges in Fisheries of the Cebu State College of Science and Technology System*, 1999: 16-19.
[28] STEVEN R. A. R., & YASIR I. *Effect of Substrate Differences on Seedling Growth from Seagrass Seeds Enhalus acoroides*. Makassar: Fakultas Ilmu Kelautan dan Perikanan, Universitas Hasanuddin, 2013. https://www.slideshare.net/stevenlhita/pengaruh-perbedaan-substrat-terhadap-pertumbuhan
[29] LUNING K. *Seaweed, Their Environment, Biogeography, and Ecophysiology*. USA: Wiley Interscience Publication, 1990.
[30] EFFENDI H. *Water Quality Review*. Yogyakarta, Kanisius, 2003.
[31] DIRECTORATE GENERAL OF AQUACULTURE. *Identification and Mapping of Seaweed Cultivation Development in the Core map II Region of Bintan Regency. Final report*. Directorate General of Aquaculture, 2005.
[32] KAWAROE M., BENGEN D. G., and BARAT W. Utilization of Carbon Dioxide ($CO_2$) for Optimizing Seaweed Growth Kappaphycus alvarezii. *Omni-Akuatika*, 2012: 11(15): 78–90.
[33] SYAHLUN, RAHMAN, and RUSLAINI. Growth of Seaweed (*Kappaphycus alvarezii*) Brown Strain by Vertical Method. *Jurnal Mina Laut Indonesia*, 2013, 1(1): 122-132. https://docplayer.info/31561781-Uji-pertumbuhan-rumput-laut-kappaphycus-alvarezii-strain-coklat-dengan-metode-vertikultur.html
[34] SILEA J., & MASITHA L. *Use of Bionic Fertilizer on Seaweed Plants (Eucheuma sp)*. Fakultas Perikanan dan Ilmu Kelautan, Unidayan, 2014. http://www.infodiknas.com/wpcontent/uploads/2014/11/PENGGUNAAN-PUPUK-BIONIK-PADA TANAMAN-RUMPUT-LAUT.pdf
[35] SANGKIA F. D., GERUNG G. S., and MONTOLALU R. I. Analysis of growth and quality of seaweed carrageenan *Kappaphycus alvarezii* in different locations the Banggai's Waters, Central Sulawesi. *Journal of Aquatic Science and Management*, 2018, 6(1): 22-26. https://ejournal.unsrat.ac.id/index.php/jasm/article/view/24812
[36] DANESA M., & RABIA S. Cultivation of *Caulerpa lentillifera* Using Tray and Sowing Methods in Brackishwater Pond. *Environmental Sciences*, 2016, 4(1): 23-29. https://doi.org/10.12988/ES.2016.51012

[37] DARMAWATI, R., & JAYADI E. A. Optimizing the Growth of *Caulerpa* sp Cultivated at Different Depths in Laguruda, Takalar. *Octopus Jurnal Ilmu Perikanan*, 2016, 5(1): 435-442. https://doi.org/10.26618/octopus.v5i1.672
[38] LADYBA T. *The Effect of N and P Fertilizers with Different N/P Ratios on Growth and Protein Content Chlorella sp*. Malang, Universitas Brawijaya, 2017.
[39] NASMIA, ROSYIDA E., MASYAHORO A., PUTERA F. H. A., & NATSIR S. The utilization of seaweed-based liquid organic fertilizer to stimulate *Gracilaria verrucose* growth and quality. *International Journal of Environmental Science and Technology*, 2021, 18: 1637–1644. https://doi.org/10.1007/s13762-020-02921-8
[40] CLAIRE D., MORANCAIS M., LI M., DENIAUD E., GAUDIN P., WIELGOSZ-COLLIN G., BARNATHAN G., JAOUEN P., and FLEURENCE J. Study of The Chemical Composition of Edible Red Macroalgae *Grateloupia turuturu* from Brittany. *Food Chemistry*, 2010, 119: 913-917. https://doi.org/10.1016/j.foodchem.2009.07.047
[41] YUAN, & YVONNE. Marine algal constituents. In *Marine nutraceutical and Functional Food*. Boca Raton, CRC Press, 2008: 259-296.
[42] SOELISTYOWATI D., MURNI I., and WIYOTO. Morphology of *Gracilaria* spp. Cultivated in a simple coastal village pond, Muara Gembong. *Jurnal Akuakultur Indonesia*, 2014, 13(1): 94-104. https://doi.org/10.19027/jai.13.94-104
[43] PIAZZI L., CECCHERELLI G., and CINELLI F. Threast Macroalgae Diversity: Effect of the Introduced Green Alga *C. racemosa* in the Mediterranean. *Marine Ecology Progress Series*, 2002, 2(10): 149-159. https://doi.org/10.3354/meps210149
[44] FONDRIEST. Dissolved Oxygen. *Environmental Learning Center*, 2021. http://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/
[45] ILUSTRISIMO, PALMITOS and SENAGAN. *Growth Performance of Caulerpa lentillifera (Lato) in Lowered Seawater pH*. Cebu: Philippine Science High School-Central Visayas Campus Talaytay, 2013.
[46] PERRY R. *A guide to the Marine plankton of Southern California*. University of California, Los Angeles, 2003.
[47] MURILLO Z. M., & SALAMANCA E. J. P. Effect of salinity on growth of the green alga *Caulerpa sertularioides* (Bryopsidales, Chlorophyta) under laboratory conditions. *Hidrobiológica*, 2016, 26 (2): 277-282. http://www.scielo.org.mx/pdf/hbio/v26n2/0188-8897-hbio-26-02-00277.pdf

**参考文:**

[1] PRADHIKA V. D, SURYONO, 和 SEDJATI S. 添加固体和液体肥料对生长、总叶绿素和蛋白质含量的影响总状花椰菜, 雅各布·阿加德, 1873 (菜叶藻科：花椰菜科). 海洋研究杂志, 2019, 8 (3): 269-276. https://doi.org/10.14710/jmr.v8i3.25269
[2] MAGDUGO R. P, TERME N., LANG M., PLIEGO-CORTÉS H., MARTY C., HURTADO A. Q., BEDOUX G. 和 BOURGOUGNON N. 总状花椰菜（福斯卡尔）和石莼（黛丽）的营养和保健价值分析——两种来自菲律宾的叶绿植物. 分子, 2020, 25(12): 2901. https://doi.org/10.3390/molecules25122901
[3] BLEAKLEY S., 和 HAYES M. 藻类蛋白质：提取、应用和生产挑战。食品, 2017, 6(5): 33. https://doi.org/10.3390/foods6050033
[4] QUDUS B. A. A, ABDUL R. S., PALANIVELOO K., NAGAPPAN T, SURAIZA N. R. N., WEE J. G., CHELLAPPAN D. K., CHELLIAN J., 和 KUNNATH A. P. 生物勘探栽培热带绿藻，总状花椰菜(福斯卡尔)雅各布·阿加德：关于营养特性、抗氧化能力和抗糖尿病潜力的观点. 食品, 2020, 9(9): 1313. https://doi.org/10.3390/foods9091313
[5] GAILLANDE DE C., PAYRI C., REMOISSENET G., 和 ZUBIA M. 印度洋-太平洋地区的考勒帕消费、营养价值和农业。应用生理学杂志, 2017, 29: 2249–2266. https://doi.org/10.1007/s10811-016-0912-6
[6] 菲律宾海藻工业协会. https://siap-seaweed.tripod.com/
[7] TAPOTUBUN A. M., THEODORA E., RIRY J., TAPOTUBUN E. J., FRANSINA E. G., MAILOA M. N., RIRY W. A., SETHA B., 和 RIEUWPASSA F. 海藻花椰菜定位为功能性食品。物理研究所会议系列：地球与环境科学, 2020, 517: 1-8. https://doi.org/10.1088/1755-1315/517/1/012021
[8] BOUMEDIENE H. K., 和 LOTFI B. T. 入侵绿藻考勒帕总状变种的第一次记录。奥兰湾（阿莱格利亚西部）的柱状花. 印度地质海洋科学杂志, 2019, 48(3): 335-342. http://aquaticcommons.org/26639/
[9] SUPRIADI, SYAMSUDDIN R., ABUSTANG A., 和 YASIR I. 在不同基质中生长的列维-列维总状花椰菜的生长和类胡萝卜素含量。印度尼西亚海藻杂志, 2016, 1(2): 117-122. https://journal.indoseaweedconsortium.or.id/index.php/jrli/article/view/28
[10] TANDUYAN S. N., GONZAGA R. B., 和 BENSIG V. D. 小扁豆在菲律宾宿务旧金山海域的三个不同水位的离底养殖。银河。珊瑚礁研究杂志（特刊）, 2013: 123-132. https://doi.org/10.3755/GALAXEA.15.123
[11] DAHLIA I., REJEKI S., 和 SUSILOWATI T. 不同肥料和基质剂量对小扁豆生长的影响。水产养殖管理与技术杂志, 2015, 4(4): 28-34. https://ejournal3.undip.ac.id/index.php/jamt/article/view/9802
[12] YUDASMARA G. A. 通过竹刚性象限网基质栽培海葡萄（总状花椰菜）。海洋养殖系. 巴厘新加拉惹象头神教育大学, 2014, 3(2): 468–473. http://dx.doi.org/10.23887/jst-undiksha.v3i2.4481
[13] HASBULLAH D., AKMAL, BAHRI S., AGUNG I. G. P., SUAIB M., 和 ILHAM I. 将各种类型的基础基质用作法律法规花椰菜的生产介质. 章鱼渔业科学杂志, 2014, 3(1): 244-251. https://journal.unismuh.ac.id/index.php/octopus/article/view/543
[14] EFFENDI I. 渔业生物学. 日惹：群岛图书馆基金会, 1997.
[15] MAMANG N. 苏拉威西东南部闻起来市莱克巴水域，采用菌体起源处

理的棉花幼苗生长率对种子重量的影响.
茂物：渔业与海洋科学学院茂物农业大学, 2008.
[16] AIN N., RUSWAHYUNI, 和 WIDYORINI N. 日本万登岸海岸海藻密度与不同底质的关系.
迪波尼哥罗马夸雷斯杂志, 2014, 3(1): 99-107. https://ejournal3.undip.ac.id/index.php/maquares/article/view/4426
[17] ALAM A. 塔拉勒摄政普纳加村水域海藻卡拉胶刺桉的质量.
望加锡：哈萨穆丁大学海洋和水生科学学院, 2011.
[18] DAWES C. J. 商业重要热带海藻在鸟类上的生物学。在可再生资源的海藻养殖中。阿姆斯特丹，爱思唯尔, 1987.
[19] 海洋事务和渔业部. 廖内群岛省所有岛屿国家特定战略区域分区计划 2018-2037数字41. 海洋事务和渔业部, 2018.
[20] MALTA E., GABRIEL D., 和 VERGARA J. 氮负荷和辐照度影响花椰菜(苔藓目：叶绿目)的形态、光合作用和生长。海洋生态学进展丛刊, 2005, 298: 101-114. https://doi.org/10.3354/meps298101
[21] ROLEDA M. Y., 和 HURD C. L. 海藻营养生理学：概念在水产养殖和生物修复中的应用。藻类, 2019, 58(5): 552-562. https://doi.org/10.1080/00318884.2019.1622920
[22] XIAO X., AGUSTI S., LIN F., XU C., YU Y., PAN Y., LI K., WU J., 和 DUARTE C. M. 海藻生长的资源（光和氮）和密度依赖性。海洋科学前沿, 2019, 16: 618. https://doi.org/10.3389/fmars.2019.00618
[23] MASYAHORO, 和 MAPPIRATU. 帕卢湾海藻棉花桉不同种子深度和收获时间的生长响应。媒体中苏拉威西研发中心, 2010, 3(2): 104-111. http://jurnal.untad.ac.id/jurnal/index.php/MLS/article/view/78/71
[24] HUTABARAT S. 渔业和海洋科学的水产生产力和浮游生物研究.
三宝垄，第波尼哥罗大学出版社, 2000.
[25] ALAMSJAH M. A., TJAHJANINGSIH W., 和 PRATIWI A. W. 氮磷钾肥与三重过磷酸钙复合肥对生长、水分及叶绿素a的影响. 渔业和海洋科学杂志, 2009, 1(1): 103-116. http://dx.doi.org/10.20473/jipk.v1i1.11705
[26] BERAME. 业主贝拉姆的拉托农场。卡拉维桑, 麦克坦岛, 宿务. 2003.
[27] ROMANO S. 使用人工基质在池塘中培养"拉托"（小扁豆）。宿雾州立科技学院渔业学院期刊, 1999: 16-19.
[28] STEVEN R. A. R., 和 YASIR I. 基质差异对海草种子恩哈鲁斯死角 幼苗生长的影响. 望加锡：哈桑丁大学海洋与渔业科学学院, 2013. https://www.slideshare.net/stevenlhita/pengaruh-perbedaan-substrat-terhadap-pertumbuhan
[29] LUNING K. 海藻、它们的环境、生物地理学和生态生理学。美国：威利跨科学出版物, 1990.
[30] EFFENDI H. 水质审查. 日惹，卡尼修斯, 2003.
[31] 水产养殖总局. 民丹县核心地图II区海藻养殖发展的识别和制图。总结报告。水产养殖总局, 2005.
[32] KAWAROE M., BENGEN D. G., 和 BARAT W. 利用二氧化碳优化海藻生长卡帕藻。全水产, 2012: 11(15): 78–90.
[33] SYAHLUN, RAHMAN, 和 RUSLAINI. 海藻（卡帕藻）褐株的垂直法生长.
米娜劳特印度尼西亚杂志, 2013, 1(1): 122-132. https://docplayer.info/31561781-Uji-pertumbuhan-rumput-laut-kappaphycus-alvarezii-strain-coklat-dengan-metode-vertikultur.html
[34] SILEA J., 和 MASITHA L. 仿生肥料在海藻植物（桉树）上的使用.
统一的。渔业和海洋科学学院, 2014. http://www.infodiknas.com/wpcontent/uploads/2014/11/PENGGUNAAN-PUPUK-BIONIK-PADA TANAMAN-RUMPUT-LAUT.pdf
[35] SANGKIA F. D., GERUNG G. S., 和 MONTOLALU R. I. 中苏拉威西邦盖水域不同位置的海藻卡拉胶卡帕藻的生长和质量分析。水产科学与管理杂志, 2018, 6(1): 22-26. https://ejournal.unsrat.ac.id/index.php/jasm/article/view/24812
[36] DANESA M., 和 RABIA S. 在咸水池塘中使用托盘和播种方法培育小扁豆。环境科学, 2016, 4(1): 23-29. https://doi.org/10.12988/ES.2016.51012
[37] DARMAWATI, R., 和 JAYADI E. A. 优化在塔拉拉拉古鲁达不同深度栽培的花椰菜的生长。
章鱼杂志渔业科学, 2016, 5(1): 435-442. https://doi.org/10.26618/octopus.v5i1.672
[38] LADYBA T. 不同氮磷比的氮肥和磷肥对小球藻生长和蛋白质含量的影响。玛琅，布拉维贾亚大学, 2017.
[39] NASMIA, ROSYIDA E., MASYAHORO A., PUTERA F. H. A., 和 NATSIR S. 利用海藻基液体有机肥刺激疣状江蓠生长和品质。国际环境科学与技术杂志, 2021, 18: 1637–1644. https://doi.org/10.1007/s13762-020-02921-8
[40] CLAIRE D., MORANCAIS M., LI M., DENIAUD E., GAUDIN P., WIELGOSZ-COLLIN G., BARNATHAN G., JAOUEN P., 和 FLEURENCE J. 布列塔尼食用红藻海棠的化学成分研究. 食品化学, 2010, 119: 913-917. https://doi.org/10.1016/j.foodchem.2009.07.047
[41] YUAN, 和 YVONNE. 海藻成分。在海洋营养和功能食品中。博卡拉顿，化学橡胶公司出版社, 2008: 259-296.
[42] SOELISTYOWATI D., MURNI I., 和 WIYOTO. 江蓠属的形态学。在一个简单的沿海村庄池塘中养殖, 穆拉根邦. 印度尼西亚水产养殖杂志, 2014, 13(1): 94-104. https://doi.org/10.19027/jai.13.94-104
[43] PIAZZI L., CECCHERELLI G., 和 CINELLI F. 威胁大型藻类多样性：在地中海引入绿藻总状花椰菜的影响。海洋生态进步系列, 2002, 2(10): 149-159. https://doi.org/10.3354/meps210149

[44] FONDRIEST. 溶解氧。 环境学习中心, 2021. http://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/
[45] ILUSTRISIMO, PALMITOS 和 SENAGAN. 小扁豆(拉托)在降低海水氢势中的生长性能。宿雾：菲律宾科学高中 - 中米沙鄢校区塔莱泰, 2013.
[46] PERRY R. 南加州海洋浮游生物指南。加州大学洛杉矶分校, 2003.
[47] MURILLO Z. M., 和 SALAMANCA E. J. P. 在实验室条件下，盐度对绿藻花椰菜(绿藻目、叶绿目)生长的影响。水生物学, 2016, 26 (2): 277-282. http://www.scielo.org.mx/pdf/hbio/v26n2/0188-8897-hbio-26-02-00277.pdf