Asian Journal of Fisheries and Aquatic Research

Volume 26, Issue 4, Page 1-11, 2024; Article no.AJFAR.115253
ISSN: 2582-3760

Correlation of Water Quality Parameters on Growth Performance of Seaweed (*Kappaphycus alvarezii* Doty, 1986) Cultivated with Diagonal Method

Dewi Anita [a], Wayan Kantun [b*] and Imran Lapong [c]

[a] Department of Aquaculture, Institute of Technology and Business Maritime, Indonesia.
[b] Department of Aquatic Resources, Institute of Technology and Business Maritime, Indonesia.
[c] Department of Marine Science, Institute of Technology and Business Maritime, Indonesia.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJFAR/2024/v26i4751

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/115253

Original Research Article

Received: 29/01/2024
Accepted: 02/04/2024
Published: 04/04/2024

ABSTRACT

Kappaphycus alvarezii seaweed is an exported commodity that has economic value and is a leading commodity in aquaculture. The present study aims to analyze the correlation between water quality parameters and the growth of *Kappaphycus alvarezii* seaweed using the diagonal method. A completely randomized design using three treatments and four replications was applied for the experimental design. The research was carried out from May to June 2023 in the waters of Angkue Village, Bone Regency, Indonesia. Treatment in this diagonal model was based on the length of the diagonal rope, namely 2.5 m (treatment 1), 3.5 m (treatment 2), and 4.5 m (treatment 3) of the water depth and seaweed maintained for 42 days at a water depth of five meters. The results showed that the absolute growth of seaweed was 17,537.0 g during the study, with an average of 5845.67 ± 359.34 g. In treatment 1, the absolute growth was 1368.55 ± 5.29 g; in

**Corresponding author: Email: aryakantun@gmail.com;*

treatment 2, it was 1467.83 ± 4.58 g; and in treatment 3, it was 1547.88 ± 1.24 g, with the highest growth rate and the lowest growth rate in the first week. Water quality parameters all contribute positively to seaweed growth, but those that contribute most strongly to seaweed growth are brightness, phosphate, nitrate, and salinity.

Keywords: Water Quality; quality parameters; Kappaphycus alvarezii seaweed.

1. INTRODUCTION

Seaweed is currently the leading commodity for aquaculture in Indonesia [1]. *Kappaphycus alvarezii* is well-known as a sought-after commodity for aquaculture [2]. To increase the growth and biomass and maintain the quality, quantity, and sustainability of production, seaweed is cultivated using various technologies and methods [3].

Several cultivation methods that have been widely used by seaweed farming communities include longline methods, floating rafts, off-bottom and bottom [4], and vertical technology [5,6]. Cultivation methods using longline and vertical ropes as an alternative use of the water column [7], the loose-bottom method with plant spacing to obtain optimal growth rates of *Kappaphycus alvarezii* seaweed [8], the string risline method vertically [5,9], and based on depth [10]

The most important factor in supporting seaweed growth is water quality [11]. Optimal water quality can support the healthy growth and productivity of seaweed. Significant changes in water quality can cause stress to seaweed and can even cause damage and even death. Efforts to maintain and monitor good water quality are the key to success in seaweed cultivation. Several water quality parameters, such as water temperature, are very helpful in seaweed growth activities through photosynthesis. High temperatures can cause protein denaturation, enzymes are damaged, and cell membranes become unstable, affecting the reproduction, growth, respiration, and photosynthesis of *Kappaphycus alvarezii* seaweed [12]. Salinity also greatly determines the growth of seaweed, so its condition is very important to monitor because it can be influenced by the availability of fresh water to seawater, seasons, rainfall, tides, topography, and evaporation. Acidity has a huge influence on the life of seaweed, so it is used as an indicator of water quality as a medium for living organisms. Brightness also plays an important role in supporting the survival of seaweed because it really supports the level of sunlight received due to its penetrating power into the water, which helps photosynthesis. Receiving perfect sunlight can facilitate the process of absorbing nutrients, which has a direct effect on the increase in length and weight of seaweed [13].

Seaweed obtains food through living media and the movement of water through waves and currents that occur regularly so that it can help supply nutrients, assist in absorbing nutrients, clean dirt, and contribute to the exchange of CO_2 and O_2 [13]. Waves that are not too strong, the current is not strong, and the waves are not high can help the absorption of nutrients, but if the opposite happens, it can damage the substrate and interfere with the absorption of nutrients [14]. Other elements and microelements, such as nitrate and phosphorus, are also needed by seaweed for its growth.

Several studies related to water quality requirements in cultivating K. alvarezii seaweed have been carried out [15], who researched dissolved oxygen and salinity, while [13] examined water brightness [16]. [17] researched the ideal current speed range for seaweed cultivation; [18] researched appropriate nitrate levels for seaweed growth; and [19] researched ideal phosphate levels in seaweed cultivation. Other research conducted by Maradhya et al. [20] examined the suitability of waters for sustainable seaweed (*Kappaphycus alvarezii*) cultivation to support a science technopark. Duarte et al. [21] researched the role of seaweed cultivation in mitigating and adapting to climate change.

Based on several previous studies, measuring water quality in seaweed cultivation is still partial and not comprehensive in one study, so it is not able to provide strong information. In this regard, it is very important for this research to be carried out by carrying out complete water quality observations at one research location, at a cultivation location that applies the diagonal model cultivation method. This method is applied by considering optimizing the use of the water column based on water depth to support increased production and reduce conflicts over the use of water land as cultivation land. This research aims to analyze the contribution of water quality parameters to supporting the growth of *Kappaphycus alvarezii* seaweed.

2. MATERIALS AND METHODS

2.1 Time and Place

This research was carried out in the waters of Angkue Village, Kajuara District, Bone Regency, South Sulawesi (Fig. 1), with a research implementation period of 42 days from May to June 2023. Water quality measurements and seaweed weighing were carried out every week. Water quality observations were carried out in the morning from 09.00 to 10.00 at three cultivation location installation points. Nitrate and phosphate analyses were carried out in the water quality laboratory of the Faculty of Maritime Affairs and Fisheries at Hasanuddin University, while other water quality parameters were carried out directly in the field during the research.

The materials and equipment used in this research were *Kappaphycus alvarezii* seaweed, rigging, buoys, weights, reels, digital scales, boats, and water quality measuring equipment (thermometer, hand refractometer, pH meter, DO meter, spectrophotometer, current meter, Secchi Disk, KIT Salifert Nitrate, and KIT Hanna HI-713).

2.2 Experimental Design

This research used three treatments and four repetitions with the same water depth, namely five meters, as described below.

a) Treatment 1: 2.5 of the water depth with a rope stretching 12.5 m

b) Treatment 2: 3.5 of the water depth with a rope stretching 17.5 m

c) Treatment 3: 4.5 of the water depth with a rope stretching 22.5 m

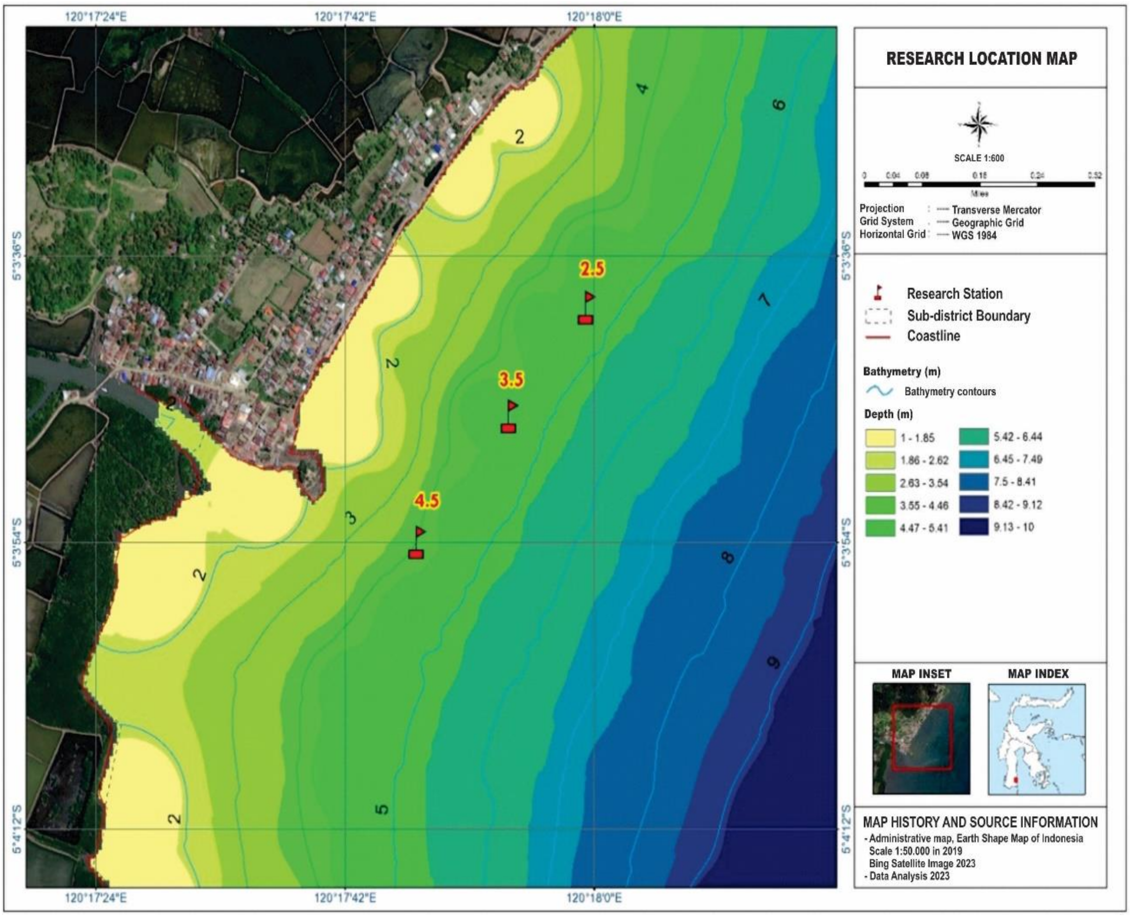

Fig. 1. Research location

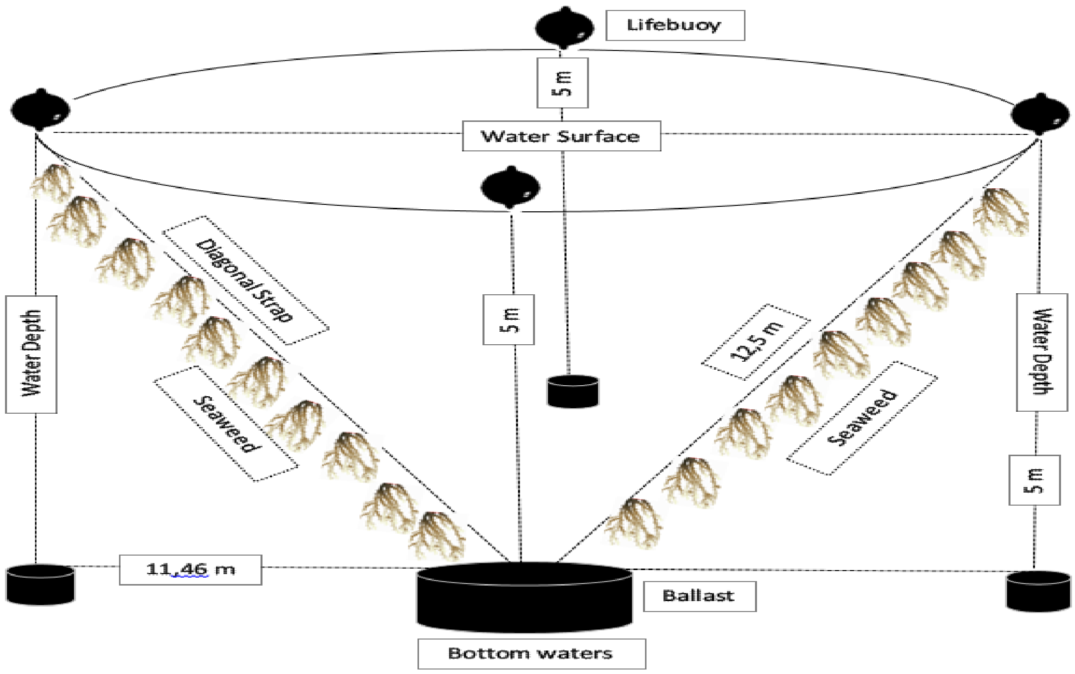

Fig. 2. Illustration of diagonal model of seaweed cultivation [22]

2.3 Preparation for Seaweed Cultivation

The installation of diagonal model technology was located far from freshwater sources (rivers). The seaweed seeds must be clean, bright, and free from adhering dirt. The seeds used were ± 20 days old, which is considered suitable for use as seeds. The seaweed seeds that have been prepared are cut into pieces and then weighed. The seedlings were tied to the main rope (diagonal stretch of rope) with a planting distance of 25 cm per cluster, and the initial seedling weight is 50 g. For the first treatment, you need 50 clumps (1250 g), for the second treatment, 70 clumps (1750 g), and for the third treatment, 90 clumps (2250 g). Each clump weighs 25 g, so a total of 5250 g of seeds were needed.

Seedlings that have been tied to stretching ropes are planted in the afternoon when the water recedes, with the installation distance between treatment models being 1.1 nm (1 nm = 1,852 km) considering the similarity of water depth, namely five meters, which is the average value of water depth that is commonly used. at the research location and provide wider space for better seaweed growth. Bio-FADs Diagonal are a type of technology that allows seaweed farming and capture fishing to work together in a single fishery [22]. The diagonal model of grass cultivation is based on this technology.

2.4 Water Sampling

Water samples were taken at a depth of 50 cm using a horizontal water sampler with a capacity of 2.2 L. One L of water samples was then put into a sample bottle and stored in a coolbox that had been filled with an ice gel pack, and the samples were analyzed for no more than 48 hours after the collection process at the research location [23].

Water nitrate content was measured using the Salifert Nitrate KIT. 1 ml of sample water was reacted with 4 drops of NO3-1 salifert nitrate reagent and 1 cup of NO3-2 for each sample [24].

After everything is given the solution, it is then vortexed until the solution is homogeneous and changes color to a purplish red. Sample measurements were carried out using a spectrophotometer with a wavelength of 540 nm.

Phosphate measurements were carried out by reacting one ml of sample water with HANNA H1713 reagent in each sample [24]. After being given the reagent, the solution is vortexed until it becomes homogeneous and changes color. Sample measurements were carried out using a spectrophotometer with a wavelength of 525 nm.

3. RESULTS AND DISCUSSION

3.1 Growth

Absolute weight growth is the difference between the increase in seaweed weight at the end of the study subtracted from the initial weight of the seaweed (Fig. 3). Based on statistical analysis using the ANOVA variance test, the results showed a significance value of $P < 0.01$ at the 99% level and continued with the BNT (Least Significant Difference) test. The results obtained were significantly different between treatments. This shows that all treatments have an influence on the absolute growth of seaweed, and all treatments are considered to tend to have the same opportunity to produce the best growth.

The growth of *Kappaphycus alvarezii* seaweed, which was cultivated using a diagonal model with three treatments, showed that the absolute growth in treatment 2.5 was 5474.2 g (31.22%), treatment 3.5 was 5867.3 g (33.46%), and treatment 4.5 amounted to 6195.5 g (35.33%). The highest absolute growth of *Kappaphycus alvarezii* was obtained in treatment 4.5, and the lowest absolute growth was obtained in treatment 2.5 times the water depth of five meters. This is thought to be related to the length of the rope used in each treatment. The longer the rope used, the smaller the angle of inclination, and if the slope is smaller, the greater the opportunity for seaweed to get sunlight to carry out the photosynthesis process. However, if the angle of inclination in this treatment is greater, the opportunity to obtain light will be less, thereby reducing the opportunity for photosynthesis. The angle of inclination of this diagonal position greatly determines the level of sunlight received, which will influence the weight gain of the cultivated seaweed.

Nursidi et al. [25] argue that light penetration is not only obtained from one side (the water surface) but from various elevation angles of light entering the water so that every part of the seaweed can receive light and produce the best growth. Sudradjat [26] revealed that light entering the water column at different depths will cause the intensity of the incoming light to be different in each water column, so that seaweed on the surface will receive light more easily than seaweed in the water column (mid).

This study obtained the weekly growth rate of seaweed as a percentage of the daily weight growth results. The weekly growth rate of seaweed during the maintenance period tends to increase. The highest specific growth yield of *Kappaphycus alvarezii* seaweed was obtained in the sixth week at 13 ± 2.23%, and the lowest growth rate occurred at the beginning of the study or in the first week at 6.8 ± 0.62% per week (Fig. 4).

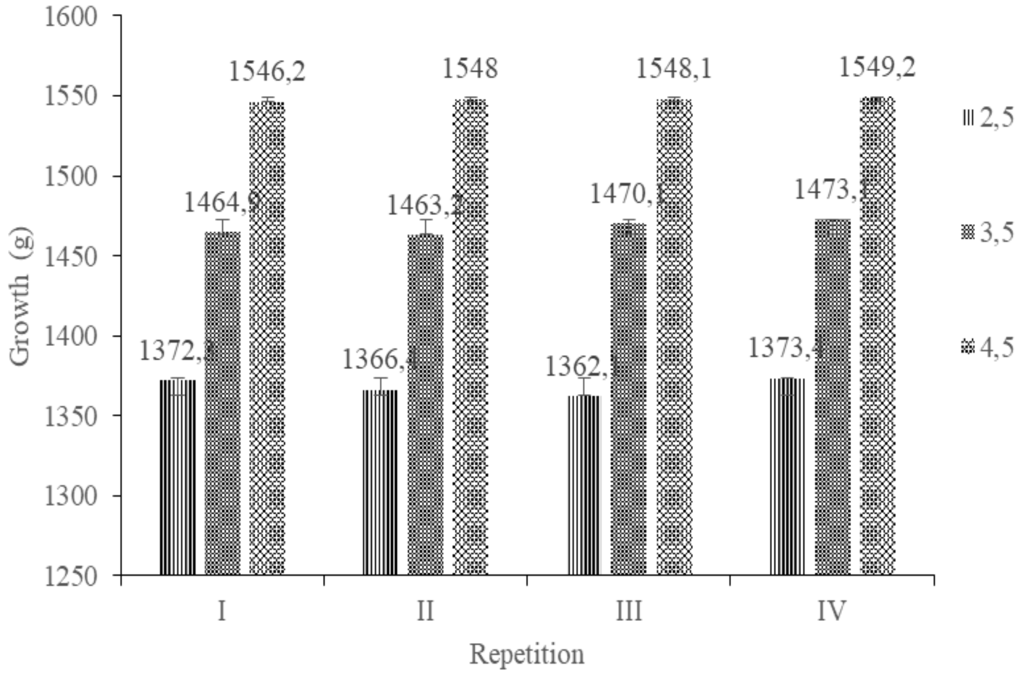

Fig. 3. Absolute growth

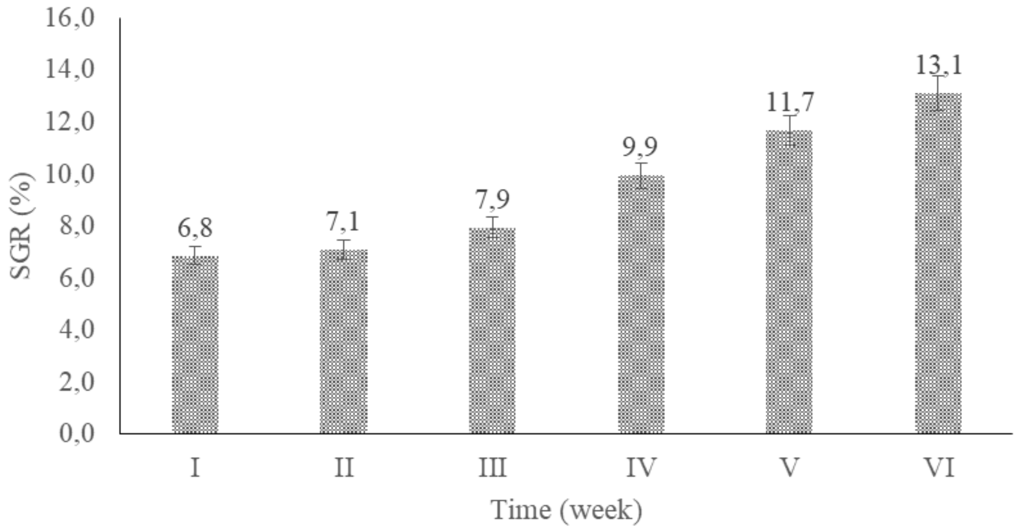

Fig. 4. Specific growth rate

The growth rate in this study was higher than the results of research conducted by Fikri et al. [2] based on depth levels to obtain daily growth rate results ranging from 1.66 ± 0.11% to 2.26 ± 0.09% per day in Bulu waters. Apart from that, the results of this growth rate are also higher compared to the results of the study by Nurqomar et al. [27], which obtained the highest specific growth rate with a value of 11.6% per day in the waters of Lekuman Island. The weight growth rate of seaweed is considered quite profitable if the percentage value (SGR) is above 3% per day [28]. The results of calculating specific rates using a diagonal pattern can be said to be profitable because the percentage growth rate of *Kappaphycus alvarezii* seaweed is still relatively good, ranging from 6.8 to 13.1% per week.

Statistical analysis using the variance test showed that $P < 0.01$ had a very significant effect on the specific growth of K. alvarezii seaweed, where the value of Fcount > Ftable (11331.30 > 4.256) and the results of the least significant difference test showed that the results between treatments were significantly different so that all treatments can achieve the highest growth rate. The growth rate of seaweed in the first week was not too large compared to the second to sixth weeks. This is predicted because, in the first week, the seaweed is still adjusting to or adapting to the new environment. In the first week, seaweed begins to adjust to environmental conditions and then begins to grow and develop in the second to sixth weeks. This statement is supported by Riris [29], which states that seven days of maintenance is the time for seaweed to acclimatize.

This means that if seaweed has gone through a phase of adaptation to its environment, its growth will automatically increase. The highest growth rate in the sixth week is thought to have occurred optimally due to the amount of sunlight each seaweed received. This statement is in accordance with the opinion of Rukisah et al. [30] that seaweed that receives more light tends to have a better growth rate.

3.2 Water Quality Parameters

Water quality observations include temperature, pH, current, salinity, brightness, DO, nitrate, and phosphate, which are measured once a week during maintenance. Water quality is one of the supporting factors in the growth of seaweed. In accordance with the opinion of Harun et al. [11], one of the most important factors in supporting the growth of seaweed is water quality. Water quality, such as temperature, based on measurements during the research ranged from 28–29 °C and is still considered optimal for supporting seaweed growth [31]. High water temperatures can have an impact on increasing salinity, which can affect the lack of dissolved oxygen supply and inhibit nutrient absorption and the growth rate of seaweed. Thus, the expected temperature must be optimal for seaweed.

Dissolved oxygen and salinity obtained during the research ranged from 5.1–7.3 ppm and 29–

33 ppt, respectively, which is the range that is still tolerated by seaweed to grow and is suitable for supporting the growth of seaweed, especially *Kappaphycus alvarezii*. Other researchers obtained dissolved oxygen ranging from 3–8 ppm [32] and a range of 28–34 ppt in salinity [15,31] (Table 1).

Based on the results of the regression analysis, it shows that temperature has a strong influence on the growth rate, while salinity has a very strong influence on the growth rate of seaweed, and dissolved oxygen only has a sufficient contribution of 8.1% to the growth rate of seaweed (Table 2).

Apart from that, increasing water temperature also has an impact on the high level of water brightness. The brightness obtained ranges from 134–279 cm. The lowest brightness was obtained in the first week of measurements, and the highest brightness level was obtained in the sixth week (end of the study). Based on the regression results, it shows that the brightness obtained during the research greatly influences the growth rate of seaweed, where the brightness obtained is 93.76%, indicating that the brightness at the research location makes a very strong contribution to the penetration of sunlight into the water column so that the seaweed can grow better. The feasibility category for seaweed cultivation still includes this brightness. Risnawati et al. [13] stated that a water brightness level of > one meter is a good brightness level for seaweed cultivation activities, so this indicates that under the conditions, the brightness level obtained at the research location is considered suitable for seaweed cultivation.

Apart from that, the pH value obtained during the research ranged from 6.9 to 8.2, and this value is still considered appropriate. Based on the results of the regression analysis, it shows that the pH at the research location makes a sufficient contribution (51.5%) to the growth rate of seaweed. If the pH value obtained is too high, it can be dangerous for the survival of seaweed. Boedi et al. [16] said that the pH value of water suitable for seaweed is around 6–9, while [37] argue that seaweed growth is very good at a pH ranging from 7.5–8.0.

Water current plays a role in the movement of nutrients in the waters because currents can carry oxygen and nutrients needed for the growth of seaweed in the waters. Sufficient currents in the waters can distribute nutrients to seaweed so that it can grow, develop, and clean up the dirt stuck to the seaweed. The study obtained a current speed range of 0.22–0.3 m/sec. These results are still considered optimal for seaweed growth. Based on regression analysis, it shows that the current speed of this location has a sufficient influence (contribution) (32.67%) on nutrient absorption and seaweed growth rate. Pauwah et al. [17] says that the ideal current speed range for seaweed cultivation is 0.2–0.4 m/sec.

The study obtained nitrate levels ranging from 0.014 to 0.663 ppm, with the highest levels occurring in the second week and the lowest in the fifth week. Based on the regression analysis, it shows that there is a very strong influence, which means that the nitrate obtained provides a very strong contribution of 71.60% to the growth rate of seaweed, in accordance with the opinion of Asni [35], which states that the appropriate nitrate level for seaweed growth is in the range of 0.01–1.20 ppm. In contrast to the opinion of Andreyan et al. [18], which states that the appropriate range of nitrate levels for seaweed growth is 0.9–3.5 ppm.

The study obtained phosphate levels ranging from 0.008 to 0.087 ppm, with the highest levels occurring in the sixth week and the lowest in the first week. Based on the regression analysis, the

Table 1. Water quality parameter values

Parameter	Value	Standard	Reference
Temperature	28-29ºC	26-30ºC	[33]
pH	6,9-8,2	6-9	[16]
Current	0,22-0,3 m/s	0,2-0,4 m/s	[17]
Salinity	29-33 ppt	28-34 ppt	[15]
Brightness	134-279 cm	> 1 m	[13]
Depth	5 m	0,3-0,8	[34]
DO	5,1-7,3 ppm	3-8 ppm	[34]
Nitrate	0,014-0,663 mg/l	0,01-1,20 ppm	[35]
Phosphate	0,008-0,087 ppt	> 0,1 ppt	[36]

Table 2. Correlation values between seaweed growth and water quality parameters

Water quality parameters	Determination value (R^2)	Corelation value (r)	Status
Temperature	0,5245	0,7242	Strong
pH	0,515	0,0362	Enough
Current	0,3267	0,5716	Enough
Salinity	0,6584	0,8114	Very Strong
Turbidity	0,9376	0,9683	Very Strong
DO	0,0814	0,2853	Enough
Nitrate	0,716	0,8462	Very Strong
Phosphate	0,7778	0,8819	Very Strong

phosphate levels found to have a strong correlation (contribution) with the growth rate of seaweed (77.28%). This means that the phosphate levels in the water where the plants will be grown are still good for growing. In line with the opinion of Daud [19], adequate phosphate levels in seaweed waters range from 0.014–0.0877 ppm.

This study uses a depth factor of five meters to cultivate seaweed, specifically *Kappaphycus alvarezii*. The seaweed growth rate obtained during this research varied at each treatment point; this was caused by the light received in each column or the tilt angle of the diagonal model applied in the research. Ismianti [38] asserted that the seaweed absorbs sunlight differently at each water depth. Madina et al. [39] obtained that the oceanographic parameters that contribute very strongly to the cultivation of *Kappaphycus alvarezii* seaweed in Takalar waters are temperature, brightness, and depth [40-41].

4. CONCLUSIONS

The highest absolute growth rate of seaweed was obtained in treatment 4.5, with growth reaching 6195.5 g (35.33%), and the lowest growth in treatment 2.5 was 5474.2 g (31.22%). The highest growth rate was obtained in the sixth week (13 ± 2.23%) per week, and the lowest growth rate was obtained in the first week (6.8 ± 0.62%) per week. Water quality parameters all contribute positively to seaweed growth. Water quality parameters that contribute strongly to seaweed growth are brightness, phosphate, nitrate, and salinity.

ACKNOWLEDGEMENTS

The author would like to thank the seaweed farming community for their kind assistance during data collection.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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