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The Effect of Carbon Absorption on Seaweed (*Kappaphycus Alvarezii*) with Vertical Rope Method at Different Depths

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A R T I C L E I N F O

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A B S T R A C T

This study aims to determine the most optimal planting depth for the growth and absorption of carbon by *Kappaphycus alvarezii* seaweed. The cultivation of the red variant of K. alvarezii was carried out using the longline method or long rope. Each seed weigh-ing 40 grams was tied to a rope that was stretched in sea waters with the help of buoys and weights to keep it in the water column. This study used a Completely Randomized Design (CRD) with four treat-ments, namely planting depths of 20 cm, 40 cm, 60 cm, and 90 cm from sea level, each with four replica-tions. The parameters observed included the absolute growth of K. alvarezii, carbon absorption capaci-ty, and water quality at the cultivation location. The results showed that the highest growth was achieved at a depth of 20 cm from sea level. However, despite the variation in depth, carbon absorption did not significantly affect the absolute growth of seaweed. In addition, no significant differences were found in carbon absorption values between depth treatments. This indicates that variations in planting depth do not affect carbon absorption capacity, possibly because carbon levels from atmospheric pollution at the research location are still relatively low

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INTRODUCTION

Seaweed has long been utilized by humans as a food source, taking various forms such as salads, vegetables, pickles, sweets, and cakes, as well as being used in cosmetic and pharmaceutical products ((Anggadiredja et al., 2006); (Kordi, 2010)). With the advancement of technology and increasing industrial demand, the use of seaweed has expanded into numerous industrial sectors. This expansion is mainly attributed to the presence of chemical compounds such as alginate in brown algae, and agar and carrageenan in red algae. These substances are commonly used as stabilizers, emulsifiers, thickeners, and additives in various industries including cosmetics (soap, moisturizers, creams, shampoos), pharmaceuticals (tablets, ointments, capsules, insecticides, pesticides), textiles, ceramics, food, and others.

Beyond its economic value in industrial applications, Kappaphycus alvarezii also plays a vital ecological role. This seaweed is highly efficient in absorbing nitrogen, phosphorus, and carbon, thereby supporting the balance of marine ecosystems ((Komarawidjaja, 2005); (Arbit et al., 2019)). As part of coastal vegetation, seaweed has a significantly higher carbon absorption capacity compared to terrestrial plants. Several economically valuable seaweed species are globally recognized for their ability to reduce atmospheric carbon dioxide (CO_2) levels while producing biomass that can be processed as raw material for the phycocolloid industry (Kaladharan et al., 2009).

According to Zansuryani (2023), seaweed requires CO_2 for photosynthesis, and its ability to absorb this gas adds economic value while also functioning as a tool for global environmental management. Seaweed cultivation also has the potential to store organic carbon in the underlying sediment, at a rate comparable to natural blue carbon habitats—marine ecosystems capable of capturing and storing carbon, with promising potential in combating climate change (Hendra, 2025).

Therefore, seaweed farming holds great promise not only for industrial production but also as a natural carbon sink. Further research is needed to examine how planting depth affects the growth and carbon absorption capacity of K. alvarezii. This study aims to determine the optimal planting depth that ensures the best growth and maximum carbon uptake, thereby contributing to the reduction of atmospheric CO_2 emissions and helping mitigate global warming.

The cultivation of Kappaphycus alvarezii using the vertical line method offers an efficient and scalable approach for maximizing both biomass production and environmental benefits. This technique allows seaweed to grow at different depths in the water column, which can influence exposure to sunlight, nutrient availability, and water movement—all of which are key factors affecting photosynthesis and carbon uptake. Specifically, the red strain of K. alvarezii has shown promising physiological adaptability across various depth levels, making it suitable for carbon sequestration studies in marine farming systems.

Differences in planting depth can significantly affect the carbon absorption potential of seaweed due to variations in light penetration and water temperature. At shallower depths, photosynthetic rates are generally higher due to increased light availability, potentially leading to greater carbon fixation. However, deeper planting may reduce exposure to herbivores and surface disturbances, offering more stable environmental conditions. Understanding how these depth-related variables influence the growth and carbon sequestration efficiency of K. alvarezii is essential for optimizing seaweed farming practices, particularly in coastal regions where space and conditions are variable.

Moreover, the use of the red strain of K. alvarezii is of particular interest because of its high carrageenan content and robust growth characteristics. Studies have indicated that this strain can contribute significantly to carbon removal from the water column and help mitigate coastal eutrophication by absorbing excess nutrients. When cultivated at optimal depths, this strain may serve as a highly effective bioresource for both economic and ecological purposes.

By integrating carbon sequestration into the evaluation of seaweed farming, particularly with respect to depth variation, this study aims to contribute to sustainable aquaculture development. The insights gained could inform blue carbon strategies and support marine spatial planning initiatives, especially in tropical regions like Indonesia, where K. alvarezii cultivation is a major livelihood activity. Future implications include not only enhancing climate mitigation efforts but also promoting circular economy approaches within the marine-based bioindustry.

LITERATURE REVIEW

Seaweed farming has gained global attention not only for its economic potential but also for its role in climate change mitigation. Among various cultivated species, Kappaphycus alvarezii is widely recognized for its rapid growth rate and high carrageenan content, making it a key species in tropical mariculture. The red strain of K. alvarezii has been cultivated extensively in Southeast Asia, especially in Indonesia and the Philippines, and has been shown to be particularly effective in absorbing dissolved inorganic nutrients and carbon dioxide (CO_2) from the surrounding water (Neish, 2008; Zansuryani, 2023).

Previous studies have indicated that seaweed has a significantly higher carbon absorption capacity per unit area compared to terrestrial vegetation, particularly when grown under optimal environmental conditions (Duarte et al., 2017). Carbon sequestration in seaweed occurs through photosynthesis, where CO_2 is converted into organic carbon and stored in biomass or transferred to sediments. According to Chung et al. (2011), the amount of carbon captured depends on environmental factors such as light availability, nutrient concentration, and water movement—all of which are influenced by planting depth.

The vertical line method is one of the most widely used techniques in seaweed farming, allowing farmers to cultivate seaweed at different depths to optimize exposure to sunlight and water flow. Variations in depth affect photosynthetic activity, with shallow waters generally providing more light but also subjecting plants to higher temperature fluctuations and wave action. In contrast, deeper waters may offer more stable conditions but reduced light intensity (Hurtado et al., 2019). Understanding the interaction between planting depth and carbon uptake efficiency is critical for developing sustainable farming practices that contribute to both economic yield and environmental goals.

Seaweed (Kappaphycus alvarezii) and Its Potential

Kappaphycus alvarezii is one of the red seaweed species with high economic value and is widely cultivated in tropical regions, including Indonesia. This seaweed is a primary source of carrageenan, a hydrocolloid compound extensively used in the food, pharmaceutical, cosmetic, and other industrial sectors. In addition to its economic value, K. alvarezii plays an important ecological role, especially in absorbing nutrients and carbon from its surrounding environment.

The Role of Seaweed in Carbon Sequestration

As photosynthetic organisms, seaweeds require carbon dioxide (CO_2) for their met-abolic processes. Their ability to absorb CO_2 from seawater contributes to the reduction of atmospheric carbon dioxide levels. This makes seaweeds an essential component in climate change mitigation through the blue carbon mechanism. Research by Hendra T.M.L. (2025) has also demonstrated that seaweed cultivation can store organic carbon in seabed sediments, comparable to mangrove and seagrass ecosystems in terms of carbon seques-tration potential.

The cultivation method used greatly affects the growth efficiency and nutrient ab-sorption capability of seaweeds. The vertical longline method is a modern cultivation technique that allows seaweed to be suspended at different depths in the water column. This variation exposes the seaweed to different levels of light intensity, temperature, and nutrient availability (Largo et al., 2017). Such environmental factors directly influence the rate of photo-synthesis and the ability of the seaweed to absorb carbon.

The Effect of Depth on Carbon Absorption

Several studies have indicated that planting depth can significantly impact photosyn-thetic efficiency and seaweed growth. At greater depths, light penetration decreases, po-tentially reducing the photosynthesis rate and thus carbon uptake (Yunus et al., 2018). However, other factors such as water clarity, current flow, and nutrient levels also determine carbon ab-sorption performance across different depths (Arbit et al., 2019). In vertical farming systems, identifying the optimal depth is essential to achieve maximum biomass production and efficient carbon sequestration.

The Urgency and Contribution of Research

Considering the dual role of K. alvarezii as both an economic resource and an envi-ronmental carbon sink, in-depth research is needed to develop cultivation techniques that maximize these functions. Investigating the effect of planting depth using the vertical rope method on carbon uptake is crucial to promote environmentally friendly aquaculture prac-tices. Such studies are expected to provide valuable scientific insights for the sustainable development of seaweed farming in Indonesia.

This section must contain a state-of-the-art explanation. It can be explained in several ways. First, you can discuss several related papers, both about objects, methods, and their results. From there, you can explain and emphasize gaps or differences between your re-search and previous research. The second way is to combine theory with related literature and explain each theory in one sub-chapter.

METHODOLOGY

Site Selection and Preparation

This study was conducted in the waters of Bone Regency, South Sulawesi, characterized by calm conditions, high water clarity, suitable depth, and favorable water quality for seaweed cultivation. The selected site was cleaned of debris and disruptive organisms prior to the installation of cultivation structures.

Seedling Preparation

Kappphycus alvarezii (red strain) seedlings were collected from active cultivation areas near the research site. The seedlings were temporarily stored in clean seawater containers. Selection was carried out based on seedling health criteria (bright color, intact structure, and no mucus). Each selected seedling was weighed to ensure a uniform initial weight of 40 grams per bundle.

Cultivation Equipment Preparation

The tools and equipment used included:

- PE ropes for vertical hanging lines
- Floats (e.g., plastic bottles)
- Sinkers (e.g., rocks or concrete blocks)
- Digital scale
- Boat for installation and monitoring

All tools were cleaned and prepared based on the number of treatments and replications needed.

Construction of the Cultivation System (Hanging Line Method)

The cultivation system was set up using a vertical hanging line method. The ropes were suspended vertically in the water column, with one end attached to a float and the other to a sinker to maintain vertical positioning. Seaweed seedlings were tied at specific depths based on treatment.

Planting of Seedlings

Seedlings (each 40 g) were planted at different depths as follows:

- T1 = 20 cm from the sea surface
- T2 = 30 cm from the sea surface
- T3 = 40 cm from the sea surface
- T4 = 60 cm from the sea surface
- T5 = 90 cm from the sea surface

Each treatment was replicated four (4) times, resulting in 20 experimental units. The cultivation period lasted for 45 days.

Water Quality Monitoring and Maintenance

Water quality was monitored weekly, including:

- Temperature
- pH
- Salinity
- Dissolved Oxygen (DO)
- Water transparency

Routine maintenance was also performed to remove any fouling organisms or seaweed competitors from the cultivation lines, ensuring optimal growing conditions.

Seaweed Growth Calculation Formula

The growth of seaweed was measured as absolute growth using the formula adapted from Effendie (1997):

$$GR = \frac{Wt - Wo}{t}$$

Where:

GR = Absolute growth rate (g/day)

W_t = Average seaweed weight at the end of cultivation (g)

W_0 = Average initial seaweed weight (g)

t = Duration of cultivation (days)

This formula provides the daily weight gain of seaweed throughout the cultivation period.

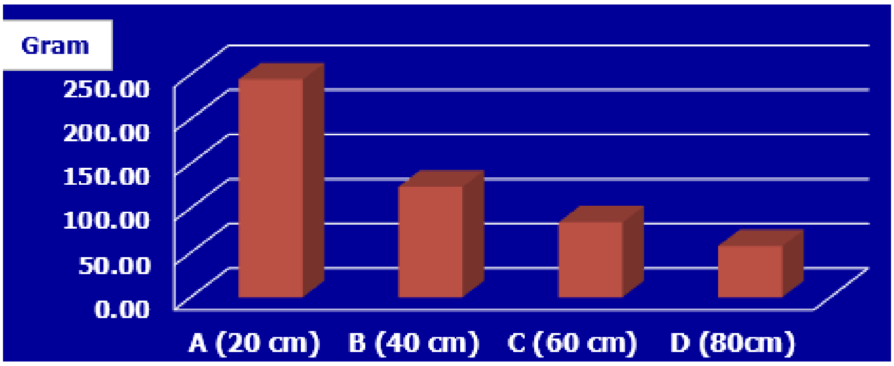
Data Analysis

Growth and carbon absorption data were analyzed using Analysis of Variance (ANOVA) to evaluate the effect of planting depth. If significant differences were observed, further analysis using Duncan's Multiple Range Test or Honestly Significant Difference (HSD) at a 5% significance level was conducted.

RESULTS AND DISCUSSION

Absolute Growth

Absolute growth results obtained from growth data collected during the cultivation period as shown in Figure 1.



Description:

(A) 20 cm weighs 244.25 g (C) 60 cm weighs 84.00 g
(B) 40 cm weighs 124.00 g (D) 90 cm weighs 57.50 g

Figure 1. Absolute Growth Histogram of K.alvarezii During Maintenance

The absolute growth of K. alvarezii during 50 days of maintenance showed the highest growth value achieved in treatment A with a planting distance from the sea surface of 20 cm, then successively lower to the lowest value in treatment

D (planting distance 90 cm from the sea surface). This is because the position of the seedlings at a depth closer to the sea surface gets the opportunity for a more optimal photosynthesis process and the availability of nutrients is absorbed more. This is in accordance with the research results of Booy et al. (2019) and Serdiati et al. (2010) that the highest growth of K. alvarezii was obtained at a depth of seedlings planted at the closest distance from the sea surface, namely 30 cm. Sea depth is one of the factors that can affect seaweed growth because according to Atmadja (1979) the role of depth on seaweed growth is related to vertical temperature stratification, light penetration, density, oxygen content and nutrients. According to Yusran et al. (2021), at a high brightness level it is optimal enough to support the growth and survival of seaweed. The clarity and turbidity of the water greatly determine the amount of sunlight intensity that enters the water column so that photosynthesis can occur optimally. Furthermore, it is explained that K. alvarezii seaweed planted at a depth of 60 cm grows slower than at a depth of 30 cm and 45 cm. This is because the movement of water caused by currents and waves only occurs on the surface so that nutrients are also less than at depths closer to the surface. This is also explained by Mubarak (1982), seaweed planted too deep has less water movement so that the process of nutrient entry into plant cells and the release of metabolic waste is hampered.

The carbon absorption value of K.alvarezii during maintenance obtained as shown in Figure 2.

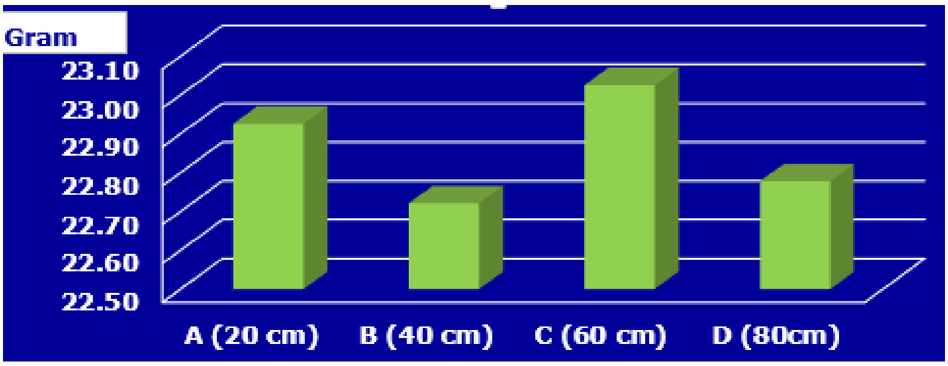


Figure 2. Carbon Absorption Value by K alvarezii During Maintenance

Carbon absorption at different planting distances showed varying values, but the values obtained between treatments showed results that were not significantly different. Thus, it can be seen that the carbon absorption of K. alvarezii red variants at different planting distances from the sea surface did not provide any differences, it is suspected that the environmental conditions in the cultivation area did not have significant differences because according to Erlania et al. (2013) that carbon absorption is related to pigment content, CO2 concentration and water clarity. It is further explained that the rate of carbon absorption by seaweed has the highest positive correlation with its external factors, namely water clarity. The clarity of the waters at the cultivation location reaches 100% so it is suspected that the photosynthesis process occurs evenly at various water depths.

Water Quality

The success of seaweed cultivation efforts cannot be separated from the conditions of the surrounding environment, especially the quality of the waters as a medium that directly affects the growth of seaweed. The results of measuring water quality parameters at the location during the cultivation period can be seen in Table 1. Referring to the table, the results of water quality measurements at the red K. alvarezii cultivation location are still within the range that is feasible for the growth of K. alvarezii seaweed cultivated in the sea.

Table 1. Results of Water Quality Measurements at the Cultivation Location during K. alvarezii Maintenance

No.	Ranges	Parameter	Unit	SNI No. 7572.2:2010
1	%	Brightness	100	100
2	^oC	Temperature	26-30	26-32
3	‰	Salinity	28-31	28-34
4	ppm	Dissolved oxygen	4,3-7,6	>6
5	-	pH	6,8-8,3	7,0-8,5

CONCLUSION

Based on the results of the study, the following conclusions were drawn:

1. The highest growth of red variant K.alvarezii seaweed was obtained in the treat-ment with a planting distance of 20 cm from the sea surface
2. Carbon absorption of seaweed at all planting distances according to treatment did not affect growth and the carbon absorption value between planting distances did not show any difference
3. The planting distance of seaweed according to depth did not affect carbon ab-sorption so it is suspected that carbon absorption from the atmosphere due to environmental pollution elements is still small.

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