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Growth Response of Kappaphycus Alvarezii at Different Depth in the Waters of Batu Bao, East Nusa Tenggara

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ABSTRACT

Seaweed is one of the important fisheries commodities with significant economic value. *Kappaphycus alvarezii*, commonly known as *Eucheuma cottoni* in the market, is a type of seaweed that produces kappa carrageenan. This research aims to determine the effective planting depth for the growth, morphological and histological changes, and the environmental parameters influencing the growth of *K. alvarezii*. The cultivation method used in this research is the longline method, and it employs a Completely Randomized Design consisting of four treatments: 15cm, 30cm, 45cm, and 60cm, with each treatment replicated five times. The data were analyzed using analysis of variance, and if significant differences were found, Duncan's post hoc test was conducted.

The research results indicate that an increase in planting depth has a significant impact on specific growth rate (SGR) and average growth rate (AGR). Deeper planting depths result in slower growth. The best depth for the growth, morphology, and histology of *K. alvarezii* during the study was observed at a depth of 15 cm. Environmental parameters such as temperature, salinity, water flow rate, water clarity, and pH have a positive influence on the growth of *K. alvarezii.*

Keywords: Growth, Morphology, Histology, K. alvarezii

Introduction

Kappaphycus alvarezii is a red seaweed species that contains the dominant pigments phycoerythrin and phycocyanin (Ismail et al., 2018). Phycoerythrin plays a role in capturing light for photosynthesis, along with chlorophyll-a (Ismail et al., 2018). *K. alvarezii* produces kappa carrageenan, which has various industrial applications in the food, cosmetic, pharmaceutical, and textile industries (Ismail et al., 2018).

The depth of water, or the depth at which the seaweed grows, is a factor that influences the growth of seaweed. Depth influences the intensity of light that penetrates the water, which in turn affects photosynthesis (Glenn & Doty, 1990). The main factors that influence the process of photosynthesis are light intensity and light quality, which can have functional and structural effects on seaweed (Luhan et al., 2014). Functional responses include tolerance, metabolic activity, reproduction, and distribution, while structural responses include changes in size, morphology, and cytoplasm (Luhan et al., 2014).

The growth of *K. alvarezii* is influenced by both internal and external factors. Internal factors include the type, strain, thallus part, and age of the seaweed, while external factors include the physical and chemical conditions of the environment and human management practices (Schmidt et al., 2010). The depth of planting is an important external factor that affects the growth, morphology, histology, and carrageenan content of seaweed (Reddy et al., 2003).

The tissue of *K. alvarezii* consists of the epidermis, outer and inner cortex layers of pseudoparenchyma, and medulla, all of which contain nuclei and plastids (Periyasamy et al., 2018). Plastids contain pigments such as chlorophyll a and b, as well as other prominent pigments that give algae their color (Periyasamy et al., 2018). The shape of plastids varies depending on the type of cell, and the nucleus of the cell functions as the central hub for cellular processes (Periyasamy et al., 2018).

Extreme environmental conditions and nutrient availability can cause changes in the morphology, histology, and carrageenan content of seaweed, which in turn affects its growth and reproduction (Prasad et al., 2010). Poor growth can be attributed to water quality parameters that do not meet the requirements for K. alvarezii, leading to stunted growth and susceptibility to pests or diseases (Prasad et al., 2010).

Previous research has shown that the growth and production of *K. alvarezii* are influenced by various factors, including the depth of the water where cultivation is carried out (Bindu & Levine, 2010). However, specific research on the growth of K. alvarezii at different depths in the waters of Batu Bao, East Nusa Tenggara is limited (Bindu & Levine, 2010). Therefore, this study aims to investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute new knowledge to the understanding of its growth in this area (Bindu & Levine, 2010).

In previous studies, it has been found that the growth of *K. alvarezii* can be influenced by factors such as temperature, light, nutrients, and water depth (Hurtado et al., 2008). The growth of seaweed can be affected by the light levels received at specific depths (Hurtado et al., 2008). Additionally, the availability of nutrients in the water can also affect the growth of seaweed (Hurtado et al., 2008). Therefore, this study will focus on the influence of water depth on the growth of *K. alvarezii* in the waters of Batu Bao, East Nusa Tenggara (Hurtado et al., 2008).

Previous studies have been conducted on the growth of *K. alvarezii* at different depths in other waters, such as São Paulo State, Brazil; Gerupuk Bay, Central Lombok, West Nusa Tenggara; and Yucatán, México (Mandal et al., 2010; Loureiro et al., 2009; Ateweberhan et al., 2014). However, there is a lack of specific research on the growth of K. alvarezii at different depths in the waters of Batu Bao, East Nusa Tenggara (Loureiro et al., 2009). Therefore, this study will contribute new knowledge to the understanding of the growth of *K. alvarezii* in this area (Loureiro et al., 2009).

It has been known from previous research that the growth of *K. alvarezii* can be influenced by water depth (Adharini et al., 2018). This study will expand our knowledge of the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara (Adharini et al., 2018). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* (Adharini et al., 2018). Additionally, this study can provide a better understanding of the environmental factors that influence the growth of this seaweed (Adharini et al., 2018).

In previous research, it has been found that the growth of *K. alvarezii* can be influenced by factors such as temperature, light, nutrients, and water depth (Adharini et al., 2020). This study will contribute to our understanding of the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa

Tenggara (Adharini et al., 2020). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Adharini et al., 2020).
The growth and production of *K. alvarezii* are influenced by various factors, including water depth (Bulboa & Paula, 2005). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Bulboa & Paula, 2005). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* (Bulboa & Paula, 2005).
In previous research, it has been found that the growth of *K. alvarezii* can be influenced by water depth (Li et al., 2016). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Li et al., 2016). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Li et al., 2016).
The growth of *K. alvarezii* can be influenced by various factors, including water depth (Yunque et al., 2010). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Yunque et al., 2010). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* (Yunque et al., 2010).
In previous research, it has been found that the growth of *K. alvarezii* can be influenced by water depth (Yuniarsih et al., 2014). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Yuniarsih et al., 2014). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Yuniarsih et al., 2014).
The growth of *K. alvarezii* can be influenced by various factors, including water depth (Rodrigueza & Montaño, 2007). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Rodrigueza & Montaño, 2007). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* (Rodrigueza & Montaño, 2007).
In previous research, it has been found that the growth of *K. alvarezii* can be influenced by water depth (Lantah et al., 2017). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Lantah et al., 2017). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Lantah et al., 2017).
The growth of *K. alvarezii* can be influenced by various factors, including water depth (Abbas et al., 2022). This study will investigate the growth of K. alvarezii at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Abbas et al., 2022). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* (Abbas et al., 2022).
In previous research, it has been found that the growth of *K. alvarezii* can be influenced by water depth (Cokrowati et al., 2020). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Cokrowati et al., 2020). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Cokrowati et al., 2020).

The growth of *K. alvarezii* can be influenced by various factors, including water depth (Muktiniati et al., 2022). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Muktiniati et al., 2022). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Muktiniati et al., 2022).

In previous research, it has been found that the growth of *K. alvarezii* can be influenced by water depth (Luhan et al., 2022). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Luhan et al., 2022). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Luhan et al., 2022).

The growth of *K. alvarezii* can be influenced by various factors, including water depth (Labenua & Aris, 2021). This study will investigate the growth of K. alvarezii at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Labenua & Aris, 2021). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Labenua & Aris, 2021).

In previous research, it has been found that the growth of *K. alvarezii* can be influenced by water depth (Aris & Tamrin, 2021). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Aris & Tamrin, 2021). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Aris & Tamrin, 2021).

The growth of K. alvarezii can be influenced by various factors, including water depth (Alibon et al., 2019). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Alibon et al., 2019). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Alibon et al., 2019).

In previous research, it has been found that the growth of *K. alvarezii* can be influenced by water depth (Logo et al., 2019). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Logo et al., 2019). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Logo et al., 2019).

The growth of *K. alvarezii* can be influenced by various factors, including water depth (Astriana et al., 2019). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Astriana et al., 2019). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Astriana et al., 2019).

In previous research, it has been found that the growth of K. alvarezii can be influenced by water depth (Castelar et al., 2009). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Castelar et al., 2009). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Castelar et al., 2009).

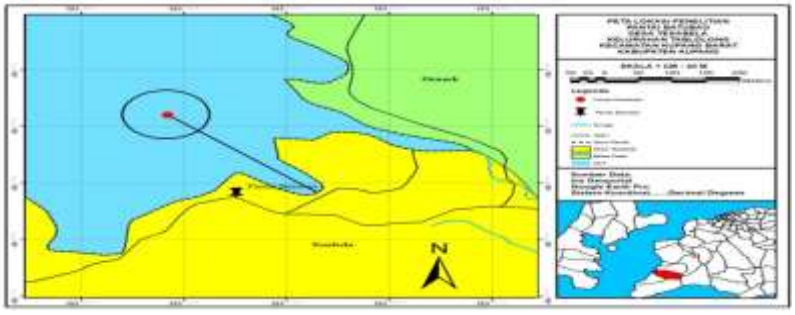
The growth of *K. alvarezii* can be influenced by various factors, including water depth (Hasnawi et al., 2016). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Hasnawi et al.,

2016). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Hasnawi et al., 2016).
In previous research, it has been found that the growth of *K. alvarezii* can be influenced by water depth (Suryati et al., 2015). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Suryati et al., 2015). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Suryati et al., 2015).
The growth of *K. alvarezii* can be influenced by various factors, including water depth (Radiarta et al., 2012). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Radiarta et al., 2012). The results of this study can provide useful information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Radiarta et al., 2012).
In previous research, it has been found that the growth of *K. alvarezii* can be influenced by water depth (Villanueva & Montaño, 2003). This study will investigate the growth of *K. alvarezii* at different depths in the waters of Batu Bao, East Nusa Tenggara, and contribute to our understanding of its growth in this area (Villanueva & Montaño, 2003). The results of this study can provide valuable information for seaweed farmers in determining the optimal depth for cultivating *K. alvarezii* in this area (Villanueva & Montaño, 2003).

RESEARCH MATERIALS & METHODS

Research sites

The location of this research was carried out in the waters of Batu Bao, East Nusa Tenggara in June-August 2023. This research used a completely randomized design (RAL) for depth treatment (P) which consisted of 4 levels: depth (P1 15cm), (P2 30cm), (P3 45cm) and (P4 60cm) with 5 repetitions (U). The method used in cultivating *K.alvarezii* seaweed is the long line method. The variables measured in this research are growth rate, morphology, histology and environmental parameters. Then the data is analyzed using ANOVA. If the test results are significantly different, they will be tested further using the Duncan test.



Picture. 1. Research location in Batu Bao Waters, East Nusa Tenggarta

Method

Sample preparation

K. alvarezii Those cultivated are measured for growth every Sunday with an initial weight of 100 grams and in the 5th week of the harvest period samples are taken from each planting depth (15cm, 30cm, 45cm and 60cm) then the morphology is observed and documented. Histological observations in the

laboratory. Environmental parameters, namely temperature (C°), current speed (cm/sec), salinity (ppt), pH, brightness (m), are measured every week 5 times (3 times/day) at the research location.

Sample Observation and Histology

Morphology of *K. Alvarezii*

Morphological observations include changes in *thallus* color, size and shape (Characteristics) carried out visually and observing every week (changes in the growth process) and comparing the color of each planting depth of the cultivated products. Akmal (2012).

Histology *K. Alvarezii*

Observation of *thallus* cell tissue (Histology) The samples were fixed for 2-36 hours, and washed with 70% ethanol, then dehydrated using ethanol with concentrations of 70%, 80%, 95% and 100% for 1 hour and clarified using xylol for 1 hour then impregnated. The sample results are then embedded in liquid paraffin (block plate) until the sample sinks, then let it sit until it solidifies and store it in the refrigerator. Tissue was cut with a microtome using a 5 µm slice method. The resulting sections were then stained using Eosin on a glass slide and dehydrated using 95% and 100% ethanol for 5 minutes so that they were ready to be observed using a microscope with 400x magnification.

RESULTS AND DISCUSSION

Characteristics of *K. Alvarezii*

In terms of morphology, seaweed does not show any differences between similar roots, stems and leaves, even though they are actually different. These shapes are called seaweed *thallus* so there are various types, including round like a tube, flat, round like a bag and hair. This *thallus* can be composed of unicellular or multicellular. *Thallus* branching is dichotomous, pectinate, pinnate, ferticillate and some are simple, unbranched. *Thallus*, some are soft (gellatious), hard because they contain lime (calcareus), soft like cartilage (cartilagenous), stringy (spongious) and so on. The physical characteristics of the *thallus* are that it is rough, slightly flat and regularly branched in two or three, the ends of the branchings are pointed and blunt with a serrated surface, somewhat rough and has nodules (Afrianto and Liviani 1933 in Syukron 2009).

Figure 2. *K. Alvarezii* taken from the waters of Batu Bao, NTT

Absolute Growth Rate

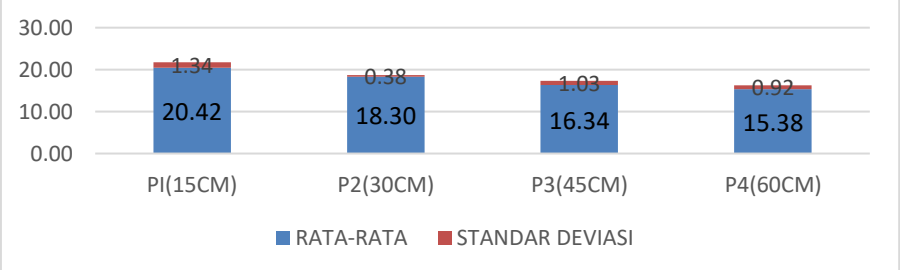


Figure 3. Absolute Growth Rate Graph

Hasil absolute growth shows that a depth of 15cm has the highest value, namely 20.42 grams. *K. alvarezii* at a depth of 15 cm, the growth of young branches or *thallus* was faster in height than at depths of 30 cm, 45 cm and 60 cm during the study. Growth is influenced by environmental factors, especially sunlight and current speed and nutrient availability (Nasir et al, 2015). The intensity of light received by seaweed at different depths affects the growth of the *thallus*. If it is planted at a distance not too far from the water surface, the surface of the new cell walls will experience changes, conversely, when planted too deep, the surface of the new cell walls will be difficult to change due to light. hampered so that the photosynthesis process does not take place properly.

The anova results on absolute growth show that there is an influence of planting depth treatment ($P < 0.05$) on the absolute growth of *K. alvarezii* seaweed. This shows that differences in planting depth have a significant effect on the absolute growth of *K. alvarezii* seaweed and the results of the Duncan test again confirm that a depth of 15 cm is significantly different from a depth of 30 cm, a depth of 45 cm and a depth of 60 cm. If seen from empirical values, a depth of 15 cm is recommended as the best planting depth.

Comparative Morphology of *K. alvarezii*

Observing the morphology of the *K. alvarzii thallus* can be explained that each depth has different results and can be seen in table 1.

Table 1. Comparison of the morphology of *K. alvarezii* on crop yields.

No	Depth 15 cm		Characteristics
1	Early seeds 	Yields 	Based on the observation results, it can be seen that *K. alvarezii* which was planted at different depths experienced changes in the color of the *thallus*. At a depth of 15 cm with changes in RGB (41%, 34%, 33%) in the initial seeds to RGB (81%, 48%, 29%), the RGB change shows that the Red color has a greater presentation so that the color at a depth of 15 cm is brighter . *K. alvarezii* shows differences in color ranging from dark brown to pale yellow after being cultivated for 42 days. This can be suspected to be related to the response to light. The intensity and color of light play a role in the adaptation of seaweed to increasing depth
2	**Depth 30 cm**		**Characteristics**
	Early seeds	Yields	Based on the observation results, it can be seen that *K. alvarezii* which was

			planted at a depth of 30 cm also experienced a change in color with a change in RGB (26%, 26%, 32%) to (45%, 30%, 23%). At a depth of 30 cm the RGB changes also experienced quite low changes, compared to a depth of 15 cm. This is thought to be due to the reception of light intensity which affects the photosynthesis process. This agrees with (Anonymous, 2005). Color variations will differ under different light conditions. *K. alvarezii* can change the appearance of its color and *thallus* when planted and grown at different depths.

3.	**Depth 45 cm**		**Characteristics**
	Early Seeds 	**Yields** 	Based on the results of observations during the research, it can be seen that *K. alvarezii* which was planted at different depths experienced changes in the color of the *thallus*. at a depth of 45 cm with changes in RGB (26%, 17%, 18%) to (62%, 55%, 49%) at a depth of 45 the color changes seen tend to be darker. Seaweed found in deeper sea waters has varying color characteristics, the *thallus* tends to be colored darker as depth increases (Doty, 1987; Landau, 1991).
4.	**Early Seeds** 	**Final seed** 	Based on the results of observations during the research, it can be seen that *K. alvarezii* which was planted at different depths experienced changes in the color of the thallus. at a depth of 60 cm with RGB changes (24%, 34%, 44%) to (43%, 30%, 26%). The thallus color at a depth of 60 cm was darker than at depths of 30 cm, 45 cm and 15 cm. The intensity and color of light play a role in the adaptation of seaweed to increasing depth. According to Thimumaran et al.,

			(2009) light intensity determines the characteristics of distribution, growth, morphology and physiology as well as productivity of seaweed. The change in seaweed color appears darker due to water conditions. According to Sahoo and Onho (2003), sea water rich in N, a constituent of chlorophyll, changes the color of the thallus to dark brown in the strain *(K. alvarezii).* Color changes at different depths are also caused by the high content of carotenoid and phycoerythrin pigments.

Histology *K. Alvarezii*

Growth and development in plants is influenced by the condition of the plant's cell structure. If the cell arrangement is denser and more orderly, the growth will be better. The results of the development of the cultivated *K. alvarezii thallus* cells can be seen in the image below.

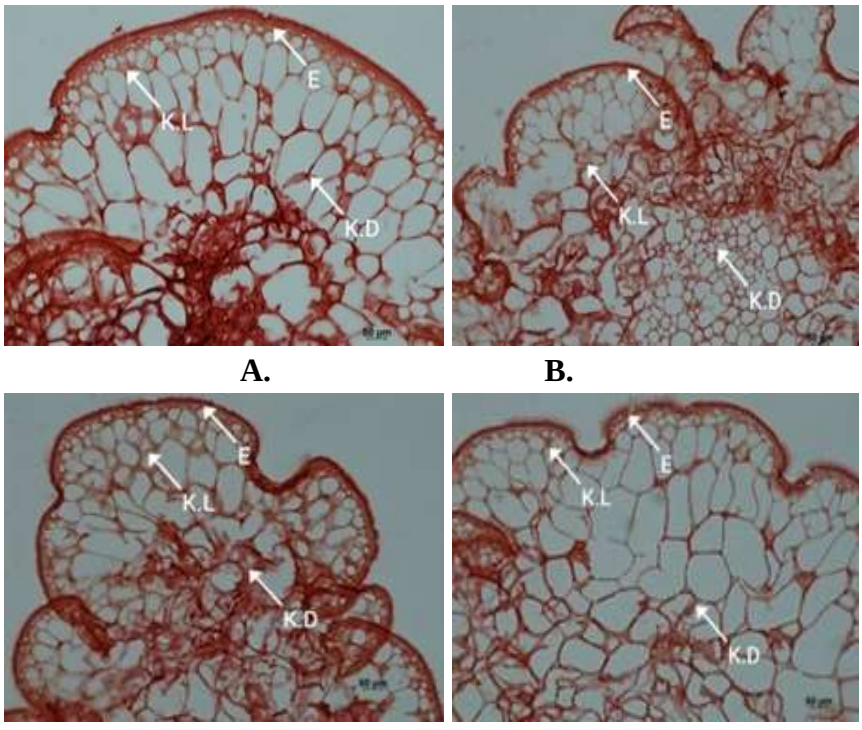


Figure 2. Cross section of *K. alvarezii thallus* (A) 15cm, (B) 30cm, (C) 45cm and (D) 60cm from cultivation in Batu Bao waters, NTT

The results of histological observations of *K. alvarezii* seaweed tissue are that at a planting depth of 15 cm, the epidermis layer is very dense, the formation of the cell walls of *K. alvarezii* develops between

the dense layers in the breakdown of the cell nucleus, the outer cortex and inner cortex are clearly visible in its good formation. because it is not directly exposed to sunlight, it has an effect on the photosynthesis process which will help the tissue in the formation of cell walls and the formation of plastids which will form the outer cortex and inner cortex to be tight and orderly. Spherical cells with vacuoles can grow up to 600 µm, so that the cortex is densely packed (Terada & Ohno, 2000).

Physical factors, namely the speed of the current, greatly influence the growth of *K. Alvarezii*, because stimulation of the current movement will help the process of osmosis of nutrients into the cells and the response to light will result in the process of cell enlargement and will be more reproductive by increasing the number of generative cells (Sri Mulyaningrum, 2015), cell structure The inner and outer cortex requires a high level of salinity so that the cell membrane obtains a higher osmotic pressure for nutrient transport. If the cortex tends to be loose and enlarged, it means that nutrient transport is not running well (salinity) because it will play a role in the cell osmoregulation process (Choi et al., 2010 and Luhan et al., 2010)

Environmental Parameters

Parameter	Average	Appropriateness	Source
Temperature	27◦C	27-32◦C	BSN, 2010
Salinity	31.33 ppt	28-34 ppt	BSN, 2010
Flow Speed	0.26m/s	0.2-0.4m/s	Anggadireda, 2008
Brightness	1.59m	>1 m	BSN, 2010
pH	7.82	7-8.5	BSN, 2010

Temperature, Salinity and Current Speed play an important role in the growth of seaweed. The average temperature value obtained is 27°C. Mujizat (2010), high water temperature means good absorption of light by the water, but different temperatures in the water layers will affect the morphology and growth of *K. alvarezii* cells. This temperature still meets the criteria for the growth of K.alvarezii seaweed. According to (BSN, 2010) the sea water temperature that is good for cultivating *K. alvarezii* seaweed ranges between 27-32◦C.

The salinity in Batubao waters was found to be around 31 ppt, this shows that the optimum salinity for *K. alvarezii* growth is around 28-34 ppt. (BSN, 2010). Salinity in the sea is influenced by several factors such as water circulation patterns, evaporation, rainfall and river water flow. The salinity of sea water and the growth of seaweed in Batubao waters have a positive impact on seaweed growth.

The average current speed at the cultivation location during the research ranged from 0.26 m/s. In carrying out the research, although there was an increase in currents, it did not cause damage and did not affect the life of seaweed. Current speed carries nutrients for growth (BSN, 2010)

Brightness is a parameter that is closely related to the amount of light penetration into waters. Sunlight energy is needed by seaweed *thallus* in the photosynthesis mechanism. At the data collection location, the brightness during the research was 1.59 meters. The brightness of sea water is still within the optimal range. According to (BSN 2010), clear sea water conditions with a transparency level of around 1.5 meters are good enough for the growth of *K. alvarezii* seaweed.

The pH value in Batubao waters was found to be around 7.8, this shows that the pH value for seaweed cultivation is around 7-8.5 which is optimal to support the survival of *K. alvarezii* (BSN, 2010)

CONCLUSION

The research findings on the growth and morphology of *K. alvarezii* planted at a depth of 15 cm, which yielded the best growth response in the waters of Batu Bao, East Nusa Tenggara (NTT), provide a crucial foundation for further research and actions. This study has offered valuable insights into the optimal conditions for this seaweed species to thrive. However, there are several aspects that warrant further investigation, such as other environmental factors influencing growth and the health of *K. alvarezii*. Additionally, a deeper understanding of tissue structure and physiological processes within the plant at a planting depth of 15 cm can provide more profound insights into growth responses. Long-term research and comparisons with other planting depths are also necessary to validate these findings. Moreover, research on the potential for commercial use, sustainable cultivation practices, and contributions to the local community and environment is vital for further exploration. Collaboration with local stakeholders and conservation efforts should also be central to the development of this research. Thus, this research can make a significant contribution to supporting sustainable and beneficial *K. alvarezii* cultivation.

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