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The Effect of Different Initial Weights on the Growth of Kappaphycus alvarezii Produced by Tissue Culture Using the Tubular Net Method in Bulu Waters, Jepara Regency

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A B S T R A C T:

Kappaphycus alvarezii is a seaweed species with multiple applications for human use and is in high demand in various countries. Seaweed farmers commonly face problems related to seedling quality and the selection of suitable culture systems. Seedlings produced through tissue culture provide an alternative solution, as they are more resistant to disease, show faster growth, and have more uniform genetic characteristics. Tubular nets are considered an alternative culture system, especially in environments with herbivorous fish as potential pests.This study examined the use of tubular nets as experimental culture units for *K. alvarezii* seedlings with initial weights of A (50 g), B (75 g), C (100 g), and D (125 g). The tubular nets used measured 50 cm in length and 20 cm in width. The aim of this study was to determine the effect of different initial seedling weights on growth, and to identify the initial weight that produced the best growth performance. The experiment employed a completely randomized design (CRD) with four treatments and four replications. Treatments A, B, C, and D had initial weights of 50, 75, 100, and 125 g, respectively. The observed variables were absolute growth rate and specific growth rate. The results showed that differences in initial weight had a significant effect (Sig. < 0.001) based on ANOVA, and were significantly different according to Duncan's test (treatments did not fall within the same column) for both absolute and specific growth rates. Optimal water quality parameters included pH, temperature, light intensity, and phosphate concentration, while less optimal parameters included salinity, current velocity, transparency, depth, and nitrate concentration. The best initial weight was treatment D (125 g), which produced an absolute growth of 244 g and a specific growth rate of 1.79%/day for tissue-cultured *K. alvarezii* cultured using the tubular net method.

Keywords: *Kappaphycus alvarezii,* tubular net, growth

1. Introduction

Seaweed plays an important role in maintaining Indonesia's aquatic ecosystems. The high demand from other countries, combined with low competitiveness, enables Indonesian seaweed to compete in the global market, both as raw materials and processed products (Adiguna et al., 2022). *Kappaphycus alvarezii* has various uses in human life, including as a gelling and thickening agent (agar) in the food industry; as antioxidant, anti-inflammatory, and antimicrobial compounds in the pharmaceutical industry; and as a pollution controller in marine environments due to its ability to absorb CO_2 during photosynthesis. Indonesia's capacity as one of the world's seaweed exporters is supported by seaweed production that continues to increase every year. In 2023, Indonesian seaweed production was dominated by *K. alvarezii*, with a volume of 7.05 million tons of dried seaweed. In October 2024, the production of dried *K. alvarezii* reached 8.02 million tons (KKP, 2024).

Seaweed farming can be considered successful when high-quality seedlings are used, optimal environmental conditions are maintained, and appropriate cultivation methods are applied. According to Ikhsan et al. (2022), *K. alvarezii* is widely cultivated because its production technology is simple and its production costs are relatively low. However, using the same seedlings repeatedly may reduce the growth rate and cellular resilience of seaweed. Irawati and Affandi (2024) stated that poor-quality seedlings result from repeated cultivation, leading to slow growth and higher susceptibility to disease. One of the ways to obtain high-quality seedlings is through tissue culture. Tissue culture is a method of aseptically isolating and multiplying plant material from tissues or cells that are isolated to regenerate and form organisms resembling the original cells (Jaelani et al., 2021).

The selection of culture units is crucial, as it can prevent seaweed loss. Appropriate culture units protect seaweed from strong currents, sediment attachment, and herbivorous fish such as rabbitfish (baronang). According to Raden et al. (2023), stable environmental conditions are a key factor in determining growth and survival during *K. alvarezii* cultivation. One of the methods used for growing tissue-cultured seedlings is the tubular net method. According to Reis et al. (2014), tubular nets can protect seaweed in muddy substrates and areas with strong bottom movement, resulting in good growth performance due to efficient energy allocation for growth. Góes and Reis (2011) further noted that reducing the initial planting weight in tubular net cultivation is necessary to maximize growth.

Using an appropriate initial seed weight determines the success of cultivation, particularly in terms of production output. The initial seed weight is an important factor influencing the growth and yield of *K. alvarezii*, especially when cultivated using the tubular net method. Differences in initial seed weight may determine how quickly seaweed adapts and grows within the tubular net system. Seedlings with suitable initial weight tend to have better growth rates because they can absorb nutrients more efficiently and withstand environmental conditions. According to Ismariani et al. (2019), variations in initial weight in *K. alvarezii* cultivation affect growth, particularly due to competition for sunlight absorption. Research on *K. alvarezii* cultivation with different initial weights using the tubular net method is still limited. Therefore, studies on varying initial weights are essential to determine the ideal weight that produces optimal growth and cultivation efficiency.

Materials and Methods

The research was conducted in the coastal waters of Bulu, at the Brackishwater Aquaculture Development Center (BBPBAP) Jepara, from 7 November 2024 to 6 January 2025. The site had a depth of 0.34 m at low tide and 1.15 m at high tide.

Tubular nets measuring 50 × 20 cm were constructed using bamboo frames with a diameter of 2 cm, assembled with rattan at the top and bottom to form a tubular structure. The frames were then covered by sewing a net (mesh size 8) around the entire frame. A total of 16 tubular nets were assembled, each containing seedlings weighing 50–125 g.

The seedlings used in this study were fifth-generation *K. alvarezii* produced through tissue culture and subsequently grown at sea. Seed selection was performed visually by observing the thallus condition, ensuring it was free from pests and diseases, had a reddish-brown color, and showed no large weight discrepancies among seedlings. The seaweed seedlings were cleaned of attached debris and organisms, then weighed according to treatment: A (50 g), B (75 g), C (100 g), and D (125 g).

Seedling installation was carried out in the afternoon at 16:00 WIB to ensure that the seaweed remained fresh and was not exposed to direct sunlight. The planting site was located 25 meters from the shoreline. Seedlings were deployed by walking and towing the tubular nets containing seaweed using a modified canoe. Planting was performed in the afternoon during calm current conditions to maintain thallus integrity. Iron stakes, 3 m in length, were driven into the substrate to a depth of 30–40%. Polyethylene rope (PE) of 8 mm diameter and 5 m length, with four planting points spaced 15 cm apart, was attached between the stakes.

This research was conducted using an experimental method. A completely randomized design (CRD) was applied with four treatments:

Treatment A: Initial weight 50 g
Treatment B: Initial weight 75 g
Treatment C: Initial weight 100 g
Treatment D: Initial weight 125 g
Each treatment was replicated four times.

The observed parameters included absolute weight gain, specific growth rate (SGR), and water quality variables.

Absolute growth was calculated using the formula by Effendie (1997):

$$W = Wt - Wo$$

where:
W = absolute growth (g)
Wt = final weight of *K. alvarezii* at the end of cultivation (g)
Wo = initial weight of *K. alvarezii* at the start of cultivation (g)

Specific Growth Rate (SGR) was calculated using the formula by Effendi (1997):

$$SGR = \frac{(\ln Wt - \ln Wo)}{t} \times 100\%$$

where:
SGR = Specific Growth Rate (%/day)
t = cultivation period (days)

The data obtained during the study, including absolute growth and specific growth rate, were analyzed using SPSS software. Data were tested for homogeneity and normality. If the data were homogeneous and normally distributed, analysis of variance (ANOVA) was performed to determine whether the treatments had significant effects. If the treatments showed significant differences ($P < 0.05$ or 0.01), a Duncan's multiple range test was applied to identify the differences among treatment means.

Results

Absolute growth

The results of the analysis of variance showed that different initial weights of tissue-cultured *K. alvarezii* had a highly significant effect on absolute growth, with Sig. < 0.001. The overall analysis of variance for the absolute growth of *K. alvarezii* during the 60-day cultivation period is presented in Figure 1. The highest absolute growth was observed in Treatment D (125 g), with a value of 244 ± 2.92, while the lowest growth was found in Treatment A (50 g), with a value of 57 ± 2.39.

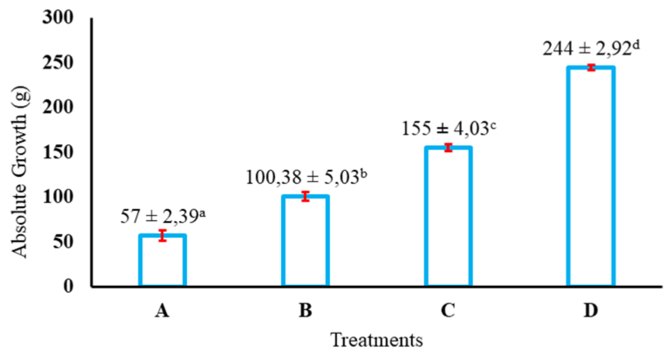

Figure 1. Absolute growth of *K. alvarezii* over 60 days.

Spesific growth rate

The results of the ANOVA analysis for specific growth rate indicated that different initial weights had a highly significant effect on the specific growth rate of *K. alvarezii*, with Sig. < 0.001. The overall analysis of variance for the specific growth rate of *K. alvarezii* during the 60-day cultivation period is presented in Figure 2. The lowest specific growth rate was observed in Treatment A (50 g), at 1.22 ± 0.108, while the highest was found in Treatment D (125 g), at 1.79 ± 0.01.

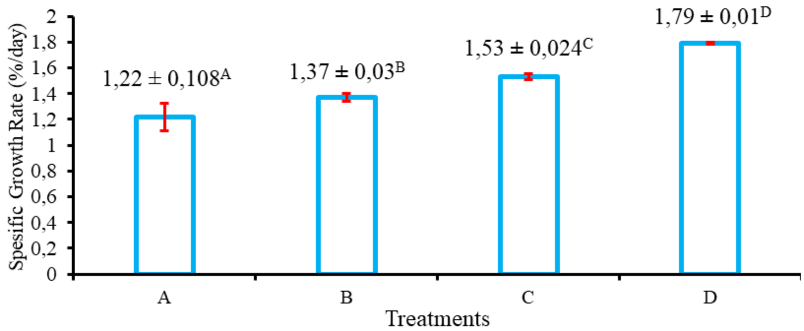

Figure 2. Specific Growth Rate of *K. alvarezii* over 60 days.

Water quality

The water quality parameters measured throughout the experiment indicated that the environmental conditions remained suitable for *K. alvarezii* cultivation (Table 1).

Table 1. Water quality parameters during the 60-day experiment based on reference values.

Parameters	Value	Standard	References
pH	7,17 - 8,58	7,0 - 8,5	SNI 7552.2 (2010)
Temperature (°C)	26,2 - 32,5	26 - 32	SNI 7552.2 (2010)
Salinity (ppt)	25 - 36	28 - 34	SNI 7552.2 (2010)
Light intensity (lux)	1.035 - 8.764	1000 - 1750	Aulia et al. (2019)
Water current (m/s)	0,1 - 0,6	0,2 - 0,5	Zainuddin and Rusdani (2018)
Secchi depth (m)	0,28 - 0,70	0,5 - 3,2	Sindopong et al. (2022)
Depth (m)	0,34 - 1,10	0,5 - 3,2	Sindopong et al. (2022)
Nitrate (mg/l)	<0,001	0,02 –0,04	Atmanisa et al. (2020)
Phosphate (mg/l)	0,055 - 0,069	0,051 – 1,00	Indriani and Sumiarsih (2003)

4. Discussions

Absolute growth

The seedlings used in this study originated from fifth-generation (F5) tissue culture that had been previously cultivated in marine conditions. According to Astriana et al. (2019), the use of fifth-generation (F5) seedlings still provides optimal results when supported by good water quality, particularly adequate light intensity for photosynthesis. The highest growth value at the final sampling was recorded in Treatment D, which increased threefold from its initial weight. The lowest growth value at the final sampling was obtained in Treatment A, which increased twofold from its initial weight. This result was also supported by Wahyudi et al. (2024), who stated that the repeated use of seedlings must be supported by ideal water conditions to compensate for the reduced seedling quality.

The application of the tubular net planting method produced significantly different effects on tissue-cultured *K. alvarezii*. Based on the data obtained, the tubular net method applied over a 60-day period showed that Treatment A (50 g) had an absolute growth value of 56 ± 2.39 g. Treatment B (75 g) reached 100.38 ± 5.03 g, Treatment C (100 g) reached 155 ± 4.03 g, and Treatment D (125 g) reached 244 ± 2.92 g. The best result from this study was obtained in Treatment D (125 g), with a final value of 244 ± 2.92 g. In the study conducted by Reis et al. (2014), the tubular net method performed better than the tie-tie method with an initial weight of 100 g. The present study conducted in Jepara over 60 days indicates that the tubular net method can be considered successful, as it resulted in satisfactory growth.

Spesific growth rate

Specific growth rate in seaweed refers to the parameter calculated based on the increase in weight or length over daily or predetermined periods. The results of the specific growth rate calculations for *K. alvarezii* showed an increase from Treatment A to Treatment D. However, this increase remained lower than the optimal growth rate typically achieved in *K. alvarezii* cultivation. In this study, the specific growth rate ranged from 1.22–1.79%/day. According to Cokrowati et al. (2019), tissue-cultured *K. alvarezii* cultivated under the same treatments (50 g, 75 g, 100 g, and 125 g) achieved specific growth rates ranging from 3.01–11.93%/day. These values indicate that the specific growth rate in the present study was not yet optimal. Rama et al. (2018) suggested that effective harvesting age for seaweed is more than 42 days, and growth is considered optimal when specific growth rate exceeds 3%/day.

The cultivation method using tubular nets in this study demonstrated high effectiveness in protecting *K. alvarezii* from herbivorous organisms commonly found in farming areas. Protection provided by the tubular net resulted in significant differences compared to other methods, as it is suitable for areas with a high abundance of herbivorous fish (Farias et al., 2025). This method is more effective in preventing damage caused by herbivore attacks, while maintaining plant stability throughout the cultivation period. A key advantage of the tubular net method is its durability, which supports commercial-scale seaweed production along exposed coastlines with high herbivory pressure (Mega-Rajan et al., 2024). The application of tubular nets is therefore an effective cultivation method for improving productivity and farming success.

Water quality

Water quality parameters are among the key factors determining the success of *K. alvarezii* cultivation. Water quality plays an essential role because it directly affects growth rate. Unsuitable water conditions may inhibit seaweed growth and increase disease risk.

The pH values recorded in this study ranged from 7.17 to 8.58. Seaweed has a tolerance range for pH fluctuations, with pH 7.0–8.5 classified as favorable for marine organisms (Yulius et al., 2017). Temperature values ranged from 26.2 to 32.5°C. Optimal temperatures for *K. alvarezii* growth range between 26–32°C, influenced by rainfall, humidity, and sunlight intensity (Sindopong et al., 2022). Salinity during the study ranged from 25–36 ppt. Some seaweed species are sensitive to high salinity levels, and the optimal salinity range for *K. alvarezii* cultivation is 28–35 ppt (Halimah et al., 2021).

Light intensity is a critical environmental factor affecting the success of *K. alvarezii* farming. The optimal light intensity range for seaweed growth is 1,035–8,764 lux. According to Wibowo et al. (2020), a light intensity range of 1,524–7,490 lux is considered suitable to support seaweed growth. Current velocity in this study ranged from 0.1–0.6 m/s, slightly higher than the standard range for *K. alvarezii*. Pauwah et al. (2020) suggested that the optimal current velocity for seaweed cultivation is 0.2–0.5 m/s. The difference observed in this study was likely caused by the cultivation period, which took place from November to January during the west monsoon, resulting in strong winds and higher water levels. These conditions likely increased both surface and subsurface currents.

Water transparency values ranged from 0.28–0.70 m. Clear waters with transparency between 0.5–2.5 m are considered suitable for seaweed growth (Aris & Ibrahim, 2020). The differences observed in transparency values in this study were caused by shallow water depth and suspended sediments being resuspended by currents.

Depth is an ecological factor influencing the success of *K. alvarezii* cultivation, as it is related to light intensity, temperature, and current movement. The depth recorded in this study ranged from 0.34–1.10 m. According to Sindopong et al. (2022), optimal depth and transparency values for seaweed cultivation are 0.5–3.2 m. Based on these criteria, the depth in this study was sufficiently optimal.

Nitrate values recorded during the study were <0.001 mg/L. The standard nitrate parameter for seaweed development is >0.04 mg/L (Hutabarat et al., 2024). The lower nitrate values may be attributed to stronger currents, which likely reduced the detectability of chemical compounds such as nitrate and phosphate. Phosphate availability in coastal waters is essential for growth rate, biomass accumulation, and carrageenan production. Phosphate concentrations in this study ranged from 0.055–0.069 mg/L. According to Erwansyah et al. (2021), optimal phosphate levels for *K. alvarezii* cultivation are >0.04 mg/L and <1.00 mg/L. Adequate phosphate availability enhances growth rate, biomass accumulation, and carrageenan production.

Conclusion

The results of this study indicate that differences in the initial biomass of tissue-cultured *K. alvarezii* seedlings cultivated using the tubular net method had a significant effect on Absolute Growth Rate and Specific Growth Rate (SGR). The initial biomass of treatment D (125 g) produced the highest absolute growth (244 g) and the highest daily Specific Growth Rate (1.79%/day).

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