Comparison of growth rate of seaweed *Kappahphycus alvarezii* using horizontal net and longline methods

Rahmad S. Patadjai, Ma'ruf Kasim, Muhammad R. Pratama

Faculty of fisheries and Marine Sciences, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia. Corresponding author: R. S. Patadjai, r.sofyanpatadjai@gmail.com

Abstract. The seaweed cultivation method has several problems that need to be considered. One of the main problems is the spread of diseases and pests that can infect seaweed. This research aims to determine the difference in growth rates of *Kappaphycus alvarezii* cultivated on horizontal nets (horinet) and longlines. This research was conducted in October-November 2022 in the waters of Bone-bone beach, Bau-bau City, Southeast Sulawesi Province. The growth of seaweed cultivated using horinets and longlines was observed, following total growth (TG) and specific growth rate (G), related to water quality parameters. The water quality parameters measured were temperature, salinity, pH, brightness, depth, current speed, nitrates, and phosphates. Seaweed cultivated on horinets had the highest TG, with an average weight of 40.5±6.2 g and the lowest using longline equipment, with an average weight of 8.2±5.2 g. The highest G on horinet was in the 1st week, with value of 5.24% day^{-1} and the lowest was in the 5th week, with of 3.08% day^{-1}. The highest G on longline was in week 1, with an average of 3.86% day^{-1}, and the lowest was in week 5, at 0.95% day^{-1}. Water quality parameters did not have a significant effect on *K. alvarezzi* seaweed.
Key Words: absolute growth, horinet, longline, specific growth, water quality.

Introduction. Seaweed has an important role as a strategic commodity that can be cultivated near coastal areas. Increased seagrass production has great potential for sustaining the lives of coastal communities (Budiyanto et al 2019; Kasim et al 2021a). One of the seaweed species that produces carrageenan with high economic value is *Kappaphycus alvarezii*. Generally, seaweed seeds are obtained from nature by cutting them from the main thallus of natural seaweed. The vegetative reproduction process of seaweed is strongly influenced by seasonal changes (Kasim et al 2021b). However, the use of natural seeds can cause a decrease in both the quality and quantity of seaweed seeds (Aris et al 2021). Carrageenan has been widely used as a main ingredient in the food, cosmetics, pharmaceutical and organic fertilizer industries (Paranrengi et al 2010). *K. alvarezii* contains high amounts of kappa type carrageenan. The shape of the thallus varies greatly, from the simplest to complex shapes, with green, yellow, gray or red colors (Nugroho & Kusnandar 2015).

Knowing the growth characteristics of seaweed is important, especially the development of length and weight. The growth of *K. alvarezii* can be influenced by external and internal factors. Thus, physical and chemical environmental conditions, together with the species, thallus and age, among others, affect growth (Syaputra 2005). In the vegetative growth phase, plants experience the growth of mature tissue cells, which results in an increase in weight. This growth phase is regulated by phytohormones, namely plant growth hormones such as auxin, gibberellin, and cytokinin, which are formed naturally in plant cells (Nursyahran & Reskiati 2013).

The seaweed cultivation method has several problems that need to be considered (Kasim et al 2019, Kasim et al 2022). One of the main problems is the spread of diseases and pests that can infect seaweed populations. In addition, environmental aspects are also a concern in seaweed cultivation methods. Determining the right location, with good water conditions and suitable substrate quality, is very important for successful cultivation. Seaweed cultivation carried out in Indonesian waters generally uses three cultivation methods: the off-bottom method, the floating raft method, and the long line method (Anggadiredja et al 2010). Seaweed cultivation methods, such as the bag method, use a variety of materials, such as polyethylene (PE) and string net bags with a mesh size of one inch (Erbabley et al 2020). The optimal growth rate of seaweed can be achieved by ensuring appropriate location selection, planting and preventing environmental pollution, which can cause disease in seaweed. The depth of the cultivation area is one of the factors that influences the speed of seaweed growth. Growth is faster at a depth of 30 cm, because the food absorption process is more efficient. In this situation, seaweed can absorb nutrients more smoothly (Maulana et al 2023). As time goes by, methods for cultivating seaweed are increasingly developing, one of the cultivation methods being the horizontal net (horinet) (Kasim et al 2020). The aim of this research is compare the daily growth rate of *Kappaphycus* cultivated using the longline and horinet methods.

Material and Method. This research was carried out for 35 days in September-October 2022, at Bone-bone beach, Bau-bau City, Southeast Sulawesi Province (Figure 1). The research site consists of 3 installation points with a distance of 100 m between them. The number of horinet and longline containers and research equipment is 3 units for each research site. Water quality observations were carried out at the research location directly, and in the laboratory of the Faculty of Fisheries and Marine Sciences, University Halu Oleo.

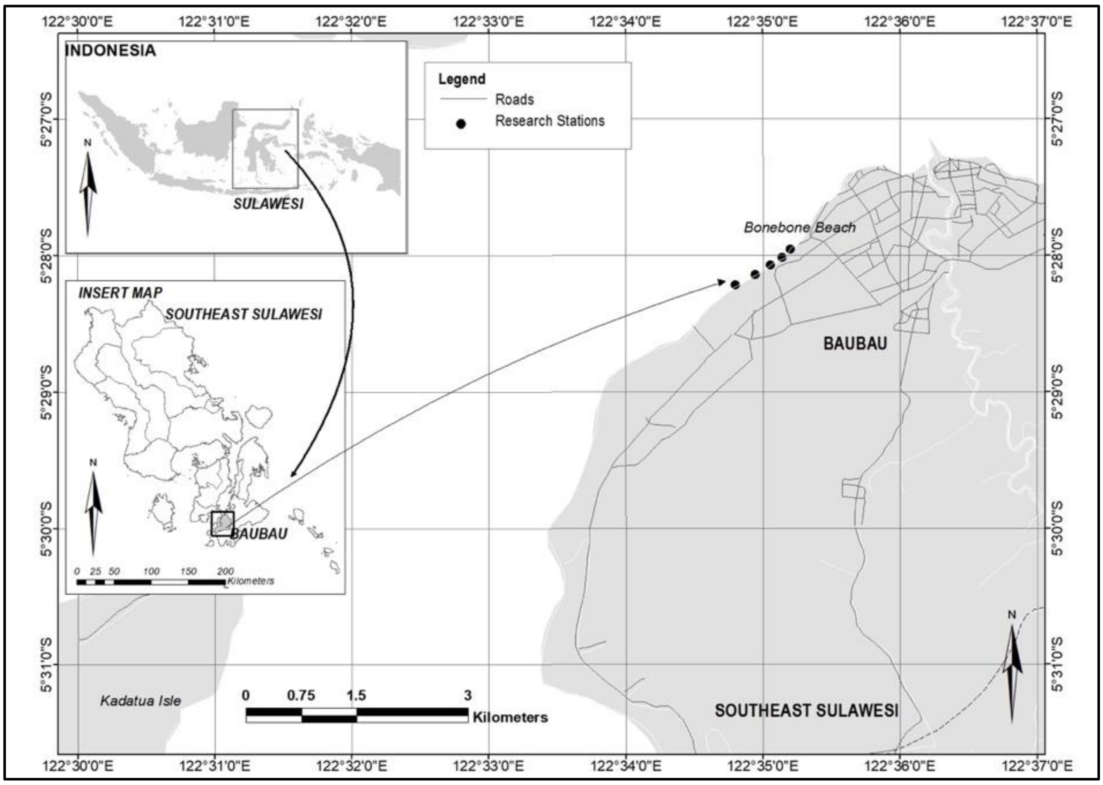

Figure 1. Study location.

The methods of cultivation used in the research were horinet and longline. The horinet consists of two main components, the left and right side bone frames and protective netting. This tool has a main frame that floats on the surface of the water on one side, while the other side sinks below the water surface. On the side of the tool, precisely on the main frame, there is a net in the form of a rectangular pocket. To keep the net above the water surface, floating ropes are tied to both sides or to the left and right sides of the main frame. The material for the left and right main frames is made from a series of pipes arranged to form an equilateral rectangle. The horinet is 180 cm long, 80 cm wide and 60 cm high. The net walls are made of multifilament material with a mesh size of 1 cm (Figure

2). The longline is made of a 50 m long rope with three stretches and a paralon pipe as a place to tie the seaweed to the rope (Figure 3).

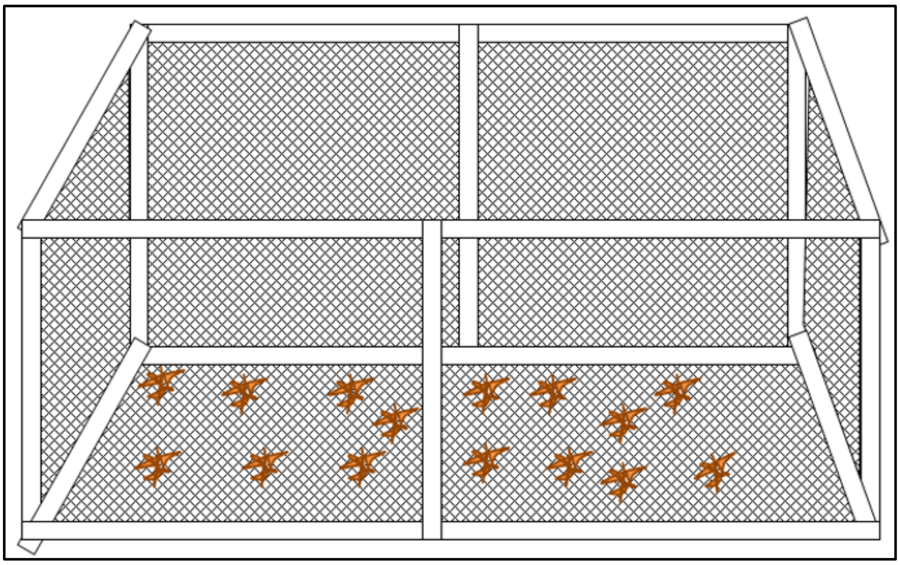

Figure 2. Horizontal net used in this research.

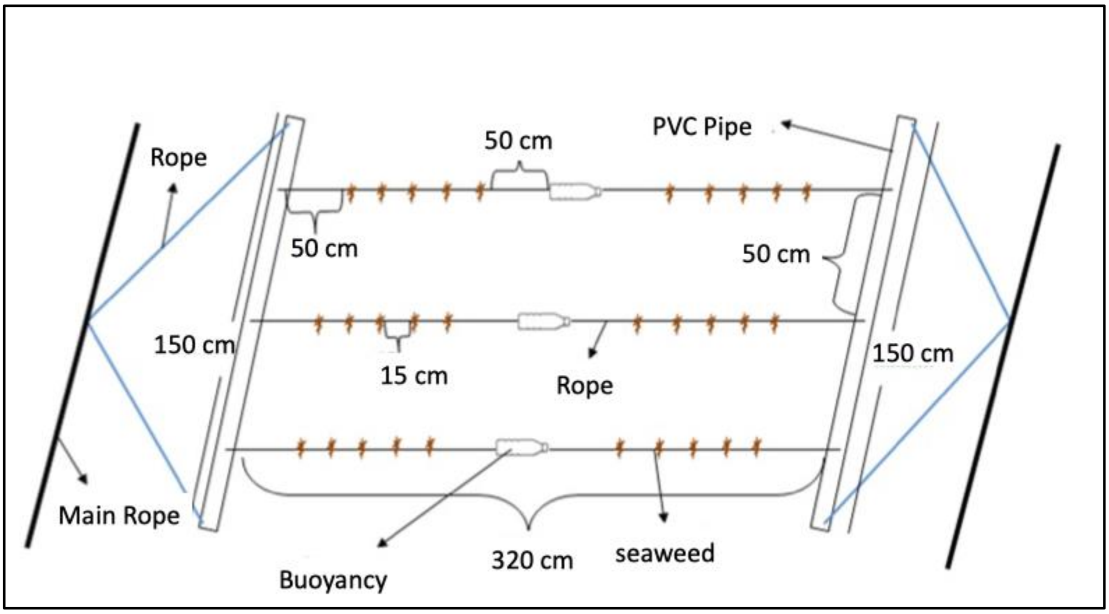

Figure 3. Longline used in this research.

The cultivation of *K. alvarezii* used seaweed thalli spread in cages. To differentiate each thallus, colored marking strings were used. For the longline method, the thalli were tied to a rope and given a colored marking rope. At each *K. alvarezii* cultivation site, 30 thalli were used with an initial weight of 20 g per thallus. The duration of maintenance was 35 days. The G of *K. alvarezii* was observed and plants were cleaned from moss and adhering dirt every 7 days. The total growth of *K. alvarezii* was obtained from the percentage value of the initial weight of seaweed during the 35 day cultivation period. Total growth is based on subtracting the initial weight of the seaweed from its final weight, which reflects the increase in weight that occurs.

Water quality measurements were carried out every 7 days at all observation stations, at the same time as the seaweed sample data collection time. Water quality data measured in the field included temperature, using a thermometer, brightness and depth, using a Secchi disk, current speed using a current meter, salinity using a hand refractometer, and pH using a digital pH meter. To measure the nitrate and phosphate content at the research location, water samples were collected at each station and immediately transported to the Laboratory of the Faculty of Fisheries and Marine Sciences, Halu Oleo University, for analysis using spectrophotometric methods.

Data analysis. Total growth was measured using digital scales. Absolute growth was calculated using the following formula (Effendie 1997):

W=Wt–Wo

Where: W - total growth (g); Wt - average weight at the end of cultivation time (g); Wo - initial average weight (g).

Determination of the specific growth rate of seaweed was calculated using the formula (Hurtado et al 2001):

$$G = \left\{ \left[\frac{Wt}{Wo} \right]^{\frac{1}{t}} - 1 \right\} x\ 100\%$$

Where: G - specific growth rate (% days^{-1}); Wt - final thallus weight (g); Wo - initial weight of thallus (g); t - research time (days).

Correlation analysis between G of seaweed and water quality parameters was conducted using the Pearson correlation test using (SPSS version 16) with a confidence level of 95%.

Results and Discussion

Total growth. The highest average value was obtained in the horinet, 40.5±6.2 g, and the lowest in the longline method, 8.2±5.2 g (Figure 4).

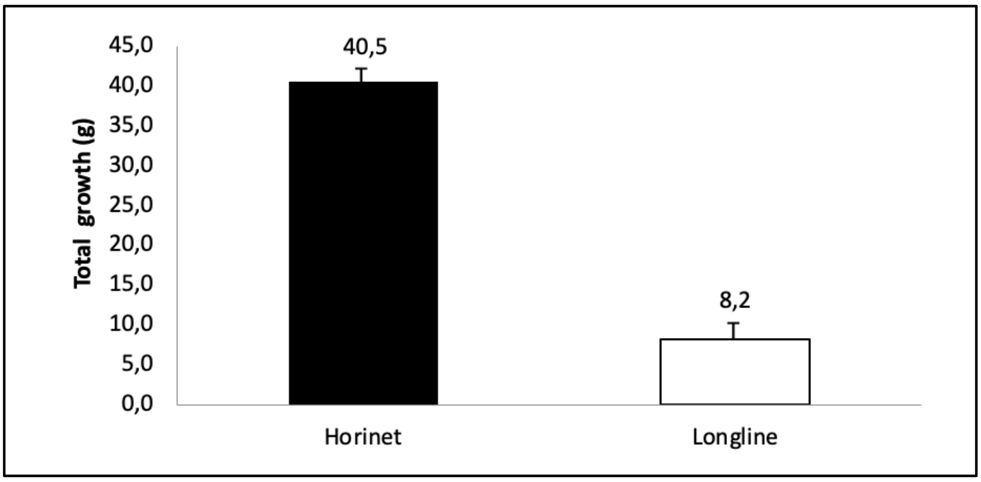

Figure 4. Total growth of *Kappahphycus alvarezii* cultivated with horinet and longline.

Growth is mostly caused by the protection that occurs in the seaweed thallus. Protection against fish feeding activities determines good growth. Horinet is a cultivation medium that can protect seaweed from attacks from various fish and other aquatic organisms (Kasim et al 2022). In addition, environmental factors such as the availability of light are also very important. This is because both methods used employ the surface of waters, where light enters easily. In *K. alvarezii* cultivation activities, there are several factors that influence the growth of seaweed, such as the presence of nutrients and the light intensity needed for the growth of new thallus stems (Novandi et al 2022).

The growth of *K. alvarezii* using horinet was better than in the longline method because the seaweed is protected by the net that covers it. Cultivating seaweed using cages produces better performances (Kasim & Asnani 2012). Enclosed seaweed has good protection from attacks (Kasim & Mustafa 2017), so that damaged cells can be repaired properly (Buamona 2021).

Specific growth rate (G). The G for the growth of *K. alvarezii* for 35 days was obtained on the horinet, at 3.08% day^{-1}, while on the longline was 0.95% day^{-1}. The G of *K. alvarezii* decreased every week until the end of the study, in both horinet and longline (Figure 5).

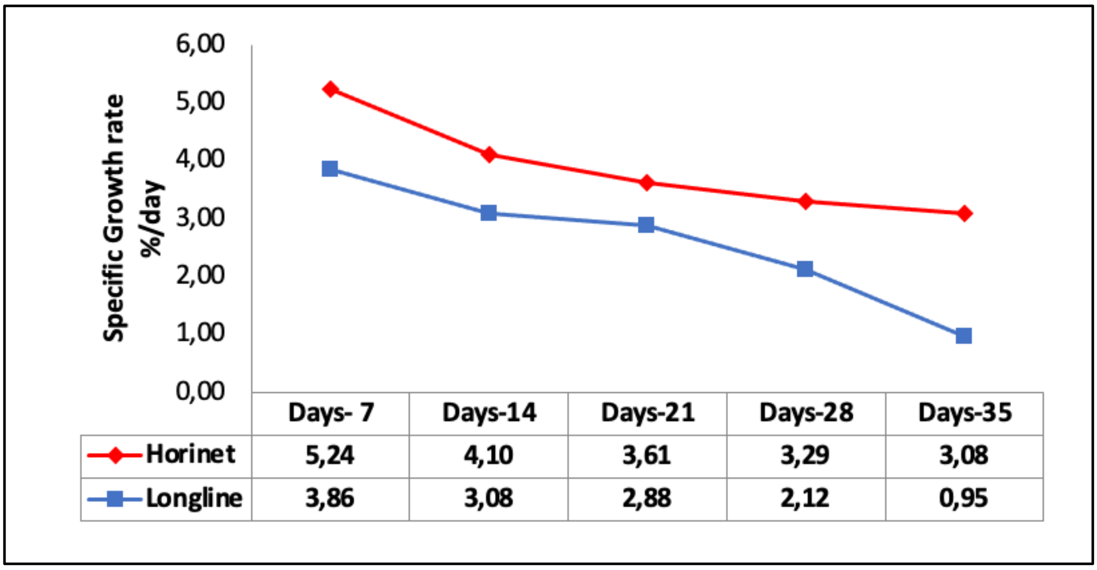

Figure 5. Specific growth rate of *Kappahphycus alvarezii* during cultivation on horinet and longline.

The G of *K. alvarezii* maintained for 35 days was relatively good on horinet, while on longline it was poor. Good growth is considered to occur when the growth rate exceeds 3%. A fairly good daily growth rate for seaweed is 2.03-2.36% (Ariyati et al 2016). The daily growth rate of seaweed with different initial weights had values of 3.26% (Sahabati et al 2016). Seaweed cultivated using long line and off-bottom methods in the coastal waters of Batukaroppa, Usto Village, Mare District, Bone Regency had specific growth rates of 3.5% and 2.9%, respectively (Halimah et al 2022). The low growth rate of *Eucheuma cottonii* in the study of Yusran (2021) was caused by the longitudinal growth pattern of *E. cottonii*. *E. cottonii* has the same growth pattern as other macro algae. It starts with the exponential stage in the first week to the 3rd week, then the stationary stage in the 4th week and it starts to decline in the 5th week until harvest (Masyahoro & Mappiratu 2010). According to the G histogram for both methods, the G value of the K. alvarezii seaweed maintained on horinet media was highest in the first week at 5.24% per day, and the lowest in the fifth week at 3.08% per day. On the other hand, the G value on the longline maintenance media was highest in the first week at 3.86% per day, and lowest in the fifth week at 0.95% per day.

Water quality. The results of water quality parameters at the research location are presented in Table 1. The water quality during the research was suitable for seaweed cultivation. Water quality parameters are strongly influenced by seasonal conditions and topography of the water area (Nursyahran & Reskiati 2013). *K. alvarezii* has tolerance to environments with parameters varying in wide ranges (Cokrowati et al 2016). Excessive intensity of sunlight into water areas can trigger a decline in water quality (Tuwo et al 2015).

Table 1

Water quality parameters during the research

Parameters	*Unit*	*Ranges*	*Values in other studies*
Temperature	°C	28-30	24- 30^{0}C (Ariyti et al 2007)
Salinity	ppt	30-35	28-35 ppt (Hardan et al 2020); 28-33 ppt (Anggadiredja et al 2010)
pH	ppm	7.6-8.6	7.7-8.3 (Ilustrisimo et al 2013)
Depth	m	2-4	1-2 (Hardan et al 2020); 4 (Haryasakti 2017)
Brightness	%	100%	92% (Jalil et al 2020)
Current velocity	m s^{-1}	0.09-4.05	0.2-0.4 (Sudradjat 2009; Anggadiredja et al 2010); 0.4 m (Hardan et al 2020)
Nitrate	mg L^{-1}	0.073-0.156	0.1-3.5 (Bolqiah et al 2018)
Phosphate	mg L^{-1}	0.029-0.048	Intermediate phosphate range of 0.0132-0.0391 mg L^{-1} and 0.081-0.0435 mg L^{-1}, obtained by Abdan et al (2013) and Ariyati et al (2007), respectively

The range of water quality during the 35 days of research was optimal for cultivating *K. alvarezii*. Good water conditions during appropriate cultivation times provide good growth and survival (Wijayanto et al 2011; Nadlir et al 2019). The results of water quality measurements during the research did not appear to influence seaweed growth.

The salinity at the research location was in accordance with quality standards. Good salinity for the growth of *K. alvarezii* is between 28-35 ppt (Kordi 2011; Pongarrang et al 2013; Ikhsan et al 2022). *K. alvarezii* is a seaweed that cannot tolerate high salinity (Sudradjat 2009).

During the research, the temperature ranged from 28-30 (°C), being good for maintaining seaweed. An acceptable temperature range for seaweed is 26-32°C (BSNI 7572.2 2010).

The pH value obtained was 7.6-8.6, suitable for maintaining seaweed, as the recommended range is 7.0-8.5 (BSNI 7572.2 2010). The pH value of water suitable for seaweed ranges from 6 to 9. In this study, a depth of 4 m was observed with a brightness value of 100%. Suitable brightness for seaweed growth is 92% (Jalil et al 2020). The depth values obtained in this study are suitable for seaweed growth.

Current speed measurements obtained during the research were 0.09-4.05 m s^{-1}. The values at the research location are good for cultivating *K. alvarezii* seaweed, even though the low current speed can supply nutrients in small amounts. Currents greatly influence growth in relation to the process of uptake of nutrients (Susilowati et al 2012). Strong currents will disturb and harm seaweed, as seaweed can break, tear and detach from the substrate (Nursidi et al 2017). A good current speed for seaweed growth is 0.2-0.4 m s^{-1} (Mudeng et al 2015). Slow current movements can increase seawater temperature and reduce the circulation of nutrients needed for the growth of seawater seaweed (Largo 2002; Nazam & Surahman 2004).

The nitrate concentration was 0.073 mg L^{-1} at the start of the study and 0.121 mg L^{-1} at the end. Phosphate concentration was 0.037 mg L^{-1} at the start of the study and 0.048 mg L^{-1} at the end. Nitrate and phosphate contents were sufficient to support the growth of *K. alvarezii*. Each algae has different nitrogen needs for optimum growth. Optimum growth of *K. alvarezii* occurs at a nitrate concentration of 0.9-3.5 ppm. At concentrations of 0.1 ppm and below, the limiting effect of nitrogen occurs, while at 45 ppm and above, the inhibitory effect begins to appear (Malingkas 2002).

Continuous monitoring of water quality in seaweed farming systems is key to maintaining productivity, preventing disease and supporting the sustainability of this sector.

Correlation analysis. The results of the correlation analysis between specific growth rate and water quality (salinity, temperature, pH, current velocity, nitrate and phosphate) are presented in Table 2.

Table 2
Correlation analysis between water quality parameters and seaweed specific growth rate (SGR)

SGR	*Temperature (^oC)*	*Salinity (ppm)*	*pH*	*Current (m s^{-1})*	*Nitrate (mg L^{-1})*	*Phosphate (mg L^{-1})*
Horinet	.033	-.786	.578	-.596	-.636	-.627
	.958	.115	.308	.289	.249	.258
Longline	-.139	-.539	.258	-.433	-.358	-.744
	.824	.349	.675	.466	.554	.149

Based on the results of the correlation analysis between temperature and the G of seaweed maintained in horinet media, the correlation coefficient is 0.033, with a significance value (p>0.05) greater than 0.05. Likewise for longline media, the correlation coefficient is -0.139, with a significance value (p>0.05). The relationship between temperature and G of seaweed in both methods showed a low relationship, with a positive trend. This means that as the temperature rises, the G tends to rise, although the impact is not significant.

Based on the results of the correlation analysis between salinity and the Gof seaweed cultured in horinet and longline, the correlation coefficients were -0.786 and -0.536, respectively, with a significance value (p>0.05). The relationship between salinity and G of seaweed in horinets shows a strong association, but in a negative direction. This means that when salinity increases, the G of seaweed tends to decrease significantly. Meanwhile, in longline media, the relationship between salinity and G is also strong and negative. Therefore, an increase in salinity in the longline method will cause a considerable decrease in the growth rate of seaweed. According to Wulandari (2023), when high salinity occurs, osmosis is affected because increasing salinity causes cells to become denser. This results in a decrease in the total fluid concentration in the explant. Based on the results of the correlation analysis between pH and the G of seaweed cultured in horinet and longline, the correlation coefficients were 0.578 and 0.258, respectively, with a significance value (p>0.05). The relationship between pH and the G of seaweed in horinet shows a fairly strong relationship in the positive direction. In other words, a significant increase in pH will cause an increase in the G of seaweed with high intensity. In contrast, in longline media, the relationship between pH and G has a low level of association. This means that increasing the pH in the longline does not have a significant impact on increasing the G of seaweed.

Based on the results of the correlation analysis between currents and the G of seaweed cultured in horinets and longlines, the correlation coefficients were -0.596 and -0.433, respectively, with a significance value (p>0.05). The relationship between current and G of seaweed in both methods shows a fairly strong relationship, but in a negative direction. This means that when the current increases, the G of seaweed on horinet and longline tends to decrease significantly, with a fairly large degree of correlation.

Based on the results of the correlation analysis between nitrate and the G of seaweed cultured with horinet and longline methods, the correlation coefficients were -0.636 and -0.358, respectively, with a significance value (p>0.05). The relationship between nitrate and the G of seaweed in horinets is strong, but has a negative direction. This means that when the nitrate concentration increases, the G of seaweed on horinet tends to decrease with high intensity. On longline media, the relationship between nitrate and G is also strong and negative. Thus, an increase in nitrate concentration in the longline method will cause a considerable decrease in the G of seaweed.

Based on the results of the correlation analysis between phosphate and G of seaweed using the horinet and longline methods, the correlation coefficients were -0.627 and -0.744, respectively, with a significance value (p>0.05). The relationship between phosphate and G of seaweed in both methods shows a strong relationship and a negative direction. In other words, an increase in phosphate concentration will cause a significant decrease in the G of seaweed in both the horinet and longline methods.

Conclusions. The highest total growth was found in seaweed cultivated in horinet, with an average value of 40.5±6.2 g, while the lowest was in the longline method, with an average value of 8.2±5.2 g. The growth of *K. alvarezii* using horinet is better because the seaweed is protected by the net that covers it. The seaweed *K. alvarezii*, which was stored in the horinet, had the highest G in the first week, averaging 5.24% per day, and the lowest in the fifth week, averaging 3.08% per day, when it was discovered in the longline. With an average value of 3.86% per day in the first week, the highest G value was recorded; the lowest, at 0.95% per day, occurred in the fifth week. The correlation between phosphate and specific growth rate of seaweed in both methods was strong, with a negative direction.

Acknowledgements. We are grateful to the Ministry of Research and Technology/BRIN of the Republic Indonesia, for the full research funding of the present research project. Gratitude for Fishery Laboratory, Faculty of Fishery and Marine Science Halu Oleo University for their assistance in sample analysis. Many thanks for LPPM UHO for facilitation of this research.

Conflict of Interest. The authors declare that there is no conflict of interest.

References

Abdan, Rahman A., Ruslaini, 2013 Effect of planting distance on the growth and carrageenan content of seaweed (*Kappahycus alvarezii*) using the long line method]. Jounal Mina Laut Indonesia 3(12):113-123. [In Indonesian].

Anggadiredja J. T., Zatnika A., Purwoto H., Istini S., 2010 [Seaweed: Cultivation, processing and marketing of potential fisheries commodities]. Penebar Swadaya Press. Jakarta. 148p. [In Indonesian].

Aris M., Muchdar F., Labenua R., 2021 [Study of seaweed *Kappaphycus alvarezii* explants growth in the different salinity concentrations]. Jurnal Ilmiah Perikanan Dan Kelautan 13(1):97-105. [In Indonesian].

Ariyati R. W., Widowati L. L., Rejeki S., 2016 [Production performance of *Eucheuma cottonii* seafood cultivated using vertical and horizontal long-line methods]. Prosiding of the V Annual National Seminar Results of Fisheries and Marine Research, pp. 332-346. [In Indonesian].

Aryati R. W., Sha'rani L., Arini E., 2007 [Karimunjawa Island and Kemujan Island water compatibility analysis, as seaweed cultivation areas using geographic information systems]. Jurnal Pasir Laut 3(1):27-45. [In Indonesian].

Boedi S., Juliati, Badrudin, 2014 Seaweed culture. *Gracilaria* sp. in pond. WWF Indonesia Fisheries, Jakarta, 20 p.

Bolqiah S., Kasim M., Afu L. O. A., 2018 [Relationship between oceanographic factors and seaweed growth using the floating net raft method in Lakorua waters, Central Mawasangka District, Central Buton Regency]. Jarnal Sapa Laut 3(1):25-36. [In Indonesian].

Buamona D. E., Nur I., Kasim M., 2021 Comparison of recovery time of *Kappaphycus alvarezii* (Doty 1985) that suffered damage from the bite of herbivorous fish kept in box nets and nets]. Media Aquatics: Scientific Journal of the Department of Aquatic Culture 6(4):154-165. [In Indonesian].

Budiyanto, Kasim M., Abadi S. Y., 2019 Growth and carrageenan content of local and tissue culture seed of *Kappaphycus alvarezii* cultivated in floating cage. AACL Bioflux 12(1):167-178.

Cokrowati N., Ria A. S., Rusman, 2016 Growth of *Kappaphycus alvarezii* seaweed from tissue culture at different planting distances. Journal of Aquatic, Coastal and Fishery Sciences, Depik 5(1):12-18. [In Indonesian].

Effendie M. I., 1997 [Fisheries biology methods]. Nusantara Library Foundation, Bogor, Indonesia, 112 p. [In Indonesian].
Erbabley N. Y. G. F., Kalebora D. M., Rettob M., 2020 [Application of bag method technology in cultivating *Eucheuma cottonii* seaweed to increase production]. Dharmakarya: Jurnal Aplikasi Ipteks untuk Masyarakat 9(1):16-20. [In Indonesian].
Halimah N., Harlina, Kasnir M., 2022 [Growth rate and production of seaweed (*Kappaphycus alvarezii*) using different cultivation methods on the coast of Mare District, Bone Regency]. National Scientific Seminar Faculty of Fisheries and Marine Sciences, Indonesian Muslim University, pp. 1-15 p. [In Indonesian].
Hardan, Warsidah, Nurdiansyah S. I., 2020 [Growth rate of *Kappaphycus alvarezii* seaweed with different planting methods in the sea waters of Sepempang Village, Natuna Regency]. Jurnal Laut Katulistiwa 3(1):14-22. [In Indonesian].
Haryasakti A., 2017 [Growth of *Kappaphycus alvarezii* at different depth levels in Perancis Bay, South Sangatta, East Kutai Regency]. Jurnal Agrifor 16(1):27-34. [In Indonesian].
Hurtado A., Critchley A., Trespoey A., 2008 Growth and carrageenan quality of *Kappaphycus striatum* var. Sacol grown at different stocking densities, duration of culture and depth. Journal of Applied Phycology 20:551-555.
Ikhsan F., Irawan H., Wulandari R., 2022 [Growth rate of green and brown varieties of *Kappaphycus alvarezii* seaweed in different cultivation methods]. Aquaculture Intek 6(1):82-91. [In Indonesian].
Ilustrisimo C. A., Palmitos A. C., Senagan R. D., 2013 Growth performance of *Caulerpa lentillifera* (lato) in lowered seawater pH. Thesis, Philippine Science High School-Central Visayas Campus Talaytay, Argao, Cebu, 28 p.
Jalil A. R., Samawi M. F., Azis H. Y., Jaya I., Malik A., Yunus I., Sohopi M. A. A., 2020 Comparison of physical-chemical conditions for seaweed cultivation in the Spermonde Archipelago, Indonesia. AACL Bioflux 13(4):2071-2082.
Kasim M., Asnani, 2012 [Determination of the season of reproduction and attachment preferences for seaweed spores (*Eucheuma cottonii*)]. Faculty of Fisheries and Marine Sciences, Halu Oleo University 17(4):209-216. [In Indonesian].
Kasim M., Balubi A. M., Astuti O., Rahman A., Patadjai R. S., Muskita W., Takwir A., Ruslaini, Bahtiar, Jalil W., 2021b Comparison between the growth of *Kappahycus alvarezii* (Rhodophyta) seed from tissue culture and clone selection cultivated using horizontal net. Egyptian Journal of Aquatic Research 47:179-184.
Kasim M., Balubi A. M., Mustafa A., Nurdin R., Patadjai R. S., Jalil W., 2020 Floating cage: A new innovation of seaweed culture. In: Emerging technologies, environment and research for sustainable aquaculture. Lu Q., Serajuddin M. (eds), IntechOpen.
Kasim M., Buamona D. E., Nur S. N., Nur I., Musaruddin M., Jalil W., 2022 Recovery of *Kappaphycus alvarezii* (Rhodophyta) thallus of due to damage by *Siganus* sp. bite and physical impacts. AACL Bioflux 15(6):2785-2797.
Kasim M., Marlia, Abdullah, Balubi A. M., Djalil W., 2019 Succession of epiphyte on thallus of *Kappaphycus alvarezii* (Rhodophyta) in horizontal net cage culture. AACL Bioflux 12(5):1710-1717.
Kasim M., Mustafa A., 2017 Comparison of growth of *Kappaphycus alvarezii* (Rhodophyta, Solieriaceae) cultivation in floating cage and longline in Indonesia. Aquaculture Reports 6:49-55.
Kasim M., Saik F., La Ola L., Nurdiana, Mansur A., Yusuf S., Balubi A. B., Jalil W., 2021a Economic analysis of *Kappaphycus alvarezii* (Rhodophyta) cultivation using the horizontal net. AACL Bioflux 14(5):2958-2968.
Kordi G. H., 2011 [Tips for successful seaweed cultivation in the sea and ponds]. Andi Publishers, Yogyakarta, Indonesia, 140 p. [In Indonesian].
Largo D. B., 2002 Recent developments in seaweed diseases. The National Seaweed Planning Workshop, Tigbauan, Iloilo, Philippines, pp. 35-42.
Malingkas R., 2002 [Propagation of *Gracilaria verrucosa* (H) Papenfus seaweed seeds through *in vitro* culture on various culture media and their applications]. Thesis, Agricultural Systems Postgraduate Program, Hasanuddin University, 83 p. [In Indonesian].

Masyahoro, Mappiratu, 2010 [Growth response at various seeding depths and harvest ages of *Eucheuma cottonii* seaweed in Palu Bay waters]. Central Sulawesi Research and Development Media 3(2):104-111. [In Indonesian].
Maulana F. W., Minsas S., Safitri I., 2023 [Growth rate of *Eucheuma cottonii* seaweed based on differences in depth using the floating net cage method in Lemukutan Island waters]. Jurnal Laut Katulistiwa 6(2):58-70. [In Indonesian].
Mudeng J. D., Magdalena E. F. K., Abdul R., 2015 [Conditions of the aquatic environment on *Kappaphycus alvarezii* seaweed cultivation land in Jayakarsa Village, North Minahasa Regency]. Journal of Aquaculture 3(1):172-186. [In Indonesian].
Nadlir A., Susilowati T., Adi K., Harwanto D., Haditomo A. H. C., Windarto S., 2019 Production performance of *Gracilaria verrucosa* using verticulture method with various wide planting area in Karimunjawa. Omni-Akuatika 15(1):47-58.
Nazam M. P., Surahman A., 2004 [Impact assessment of seaweed cultivation in West Nusa Tenggara]. Balai Pengkajian Teknologi Pertanian NTB, 35 p. [In Indonesian].
Novandi M., Irawan H., Wulandari R., 2022 [The effect of different initial seed weights on the growth rate of *Kappaphycus alverezii* seaweed using the multilevel off-board method]. Aquaculture Intek 6(1):71-82. [In Indonesian].
Nugroho E., Kusnandar E., 2015 [Seaweed agribusiness]. Swadaya Group, Jakarta, 19 p. [In Indonesian].
Nursidi, Mauli, Heriansah, 2017 Development of seaweed *Kappaphycus alvarezii* cultivation through vertical method in the water of small islands in South Sulawesi, Indonesia. AACL Bioflux 10(6):1428-1435.
Nursyahran, Reskiati, 2013 [Increased growth rate of seaweed thallus (*Kappaphycus alvarezii*) soaked in rice water with different concentrations]. Diwa Balik Journal 4(2):13-18. [In Indonesian].
Pongarrang D., Rahman A., Iba W., 2013 [Effect of planting distance and seed weight on the growth of *Kappaphycus alvarezii* seaweed using the verticulture method]. Indonesian Marine Mina Journal 3(12):94-112. [In Indonesian].
Sahabati S., Joppy D. M., Lukas L. J., 2016 [Growth of seaweed (*Kappaphycus alvarezii*) which is cultivated in mesh bags with different initial weight in the Gulf of Talengen of the Sangihe Islands]. Jurnal Budidaya Perairan 4(3):16-21. [In Indonesian].
Sudradjat A., 2009 [Cultivation of 23 profitable marine commodities]. Penebar Swadaya Press Yogyakarta, Indonesia, 172 p. [In Indonesian].
Susilowati T., Rejeki S., Nurcahaya E. D., Zulfitriani, 2012 [The effect of depth on the growth of seaweed (*Eucheuma cottonii*) cultivated using the long line method on Mlonggo Beach, Jepara Regency]. Fisheries Science Journal 8(1):7-12. [In Indonesian].
Syaputra Y., 2005 [Growth and cultivation content of cultivated seaweed *Eucheuma cottonii* in different environmental conditions and plant spacing treatments in Lhok Seudu Bay]. Thesis, Postgraduate Program, Bogor Agricultural Institute, Bogor, Indonesia, 50 p. [In Indonesian].
Tuwo A., Mulyani S., Syamsuddin R., 2015 [Relationship between physical and chemical parameters of sea water and gel strength of *Kappaphycus alvarezii* seaweed in the waters of Laikang Bay, Jeneponto Regency]. Balik Dewa Journal 6(2):52-60. [In Indonesian].
Wijayanto T., Hendri M., Aryawati R., 2011 [Study of the growth of *Eucheuma cottonii* seaweed using various planting methods in Kalianda Waters, South Lampung]. Maspari Journal 3(1):51-57. [In Indonesian].
Wulandari S. A., 2023 Determining cultivation methods based on seaweed quality (*Kappapycus alvarezii*) in Sumenep Regency. Journal of Science Education and Application 5(1):1-15.
Yusran, Tribuana H. C. P., Marhayana, 2021 [Growth rate of *Eucheuma cottonii* seaweed with different seed weights using trawl nets and long lines]. Fisheries of Wallacea Journal 2(1):95-104. [In Indonesian].
*** BSNI (Indonesian National Standards), 2010 [Production of kotoni seaweed (*Eucheuma cottonii*) – Part 2: Longline method]. BSNI 7572.2. [In Indonesian].

Received: 05 April 2024. Accepted: 10 June 2024. Published online: 22 July 2024.
Authors:
Rahmat Sofyan Patadjai, Halu Oleo University, Faculty of Fishery and Marine Sciences, Andounohu, Kampus Bumi Tridarma UHO, 93231 Kendari, Southeast Sulawesi, Indonesia, e-mail: r.sofyanpatadjai@gmail.com
Ma'ruf Kasim, Halu Oleo University, Faculty of Fishery and Marine Sciences, Andounohu, Kampus Bumi Tridarma UHO, 93231 Kendari, Southeast Sulawesi, Indonesia, e-mail: marufkasim@uho.ac.id
Muhammad Rezky Pratama, Halu Oleo University, Faculty of Fishery and Marine Sciences, Andounohu, Kampus Bumi Tridarma UHO, 93231 Kendari, Southeast Sulawesi, Indonesia, e-mail: muhammadrezkypratama@yahoo.co.id

How to cite this article:
Patadjai R. S., Kasim M., Pratama M. R., 2024 Comparison of growth rate of seaweed *Kappahphycus alvarezii* using horizontal net and longline methods. AACL Bioflux 17(4):1364-1374.