Effect of The Temperature and salinity variations on Growth and Carraggenan content Kappaphycus alvarezii in Akle Waters, Kupang Regency, East Nusa Tenggara, Indonesia

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Research Article

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Abstract

Changes in temperature, salinity water associated with growth and carrageenan content. Temperature and salinity determines the performance of seaweeds, and indeed all organisms, at the fundamental levels of enzymatic processes and metabolic function. Carrageenan is extracted from the Rhodophyceae. In this study described the ways in which changes in the environment directly affect seaweeds. We consider the extent to which seaweed may be able to respond to changes temperature and salinity. By prioritizing research in sea water we can rapidly build upon understanding of seaweed to climate change to more effectively conserve and manage coastal ecosystems. This research has been carried out from February to December. This study aimed to determine the effect of temperature and salinity on growth, nutrition and carrageenan content. The specific growth rate was 6.25% day^{-1} at 29^{0}C, 5.19% day^{-1} at 30^{0}C, 4.6% day^{-1} at 31^{0}C, 3.6% day^{-1} at 33^{0}C, 2.08%day^{-1} at 34^{0}C, and 1.9% day^{-1} at 35^{0}C, respectively. We concluded that the productivity decreased as both temperature and salinity increased. It was also observed that ice-ice disease was not present at the temperature of 29 to 32 ^{0}C and salinity from 30 to 31 psu, while ice-ice was present at temperature 33 to 35 ^{0}C and salinity of 34 to 35 psu. Carrageenan content (41.87% – 65.43%) at temperature of 29 ^{0}C – 31^{0}C, salinity 30–31 psu on March to June while at temperature 32 ^{0}C-35 ^{0}C, salinity 33–35 ppt: on July to October 7.27% – 25.20%.

Introduction

Seaweed is one of the programs in East Nusa Tenggara Province (NTT) for food security issues. For this reason, cultivation is necessary so that it can be sustainable and, at the same time, increases income and welfare for the coastal community (DKP NTT, 2020). In addition, seaweed cultivation is also strongly affected by climate change, which can influence the farmers ability to supply food for their family. Seaweed is one of the fishery commodities that has been used widely in the food industry, pharmacy, medicine, cosmetics, and many more (Oedjoe *et al*, 2019). This commodity has even been chosen as the main commodity in the fisheries revitalization program since 2005 so that cultivation is needed to be rapid and accurate to meet production demand in terms of quantity, quality and continuity by using the appropriate technology so that it can be used by farmers especially facing climate change effects (Joppy, 2015). Farmers should advance their cultivation techniques so that they may obtain maximum yields. This technique includes a cultivation system concerning site selection, types of seaweed, quality seedlings, planting methods, and cropping patterns related to seasonal changes. The development of seaweed cultivation can be influenced by the biophysical environmental conditions of the waters and climatic conditions (Radiarta *et al.*, 2012). This is due to very dynamic water conditions and the existence of climatic influences that are difficult to predict. Harvest failures that are often experienced by seaweed farmers are mostly caused by large waves, change in wind direction, salinity, fluctuating temperatures that destroy the media and cultivation biota, as well as the presence of anomalies and climates such as extremely high rainfall or prolonged summer session which can result in the emergence of a disease (ice-ice) or rotting of cultivated seaweed (Farid, 2008). Based on these conditions, it shows that climate is one of the most important factors to consider in the sustainability of seaweed cultivation. One of the limiting factors in seaweed farming is temperature. Reports showed that the response to growth of seaweed was different between times and seasons of the year (Pong-Masak et al., 2009; Harley et al, 2012,). Therefor, the purpose of this study is to report on the temperatur and salinity change to *K. alvarezii* seaweed cultivation to growth rate, carrageenan content and nutrition. It is expected that this research may be used as a reference in the management and utilization of marine cultivation areas to increase seaweed productivity optimally. Also, the results of this study can be used as basic data for determining the planting pattern of seaweed so that it can help cultivators to maximize production based on the appropriate cropping pattern.

Materials & Methods

The research was conducted in Akle Waters, Kupang Regency from April to October 2021. The data collected in this study included primary data and secondary data. Primary data are measurements of temperature and salinity from April to October 2021. In situ observations include interviews with respondents and field experiments. Respondents were selected by purposive sampling (Tongco, 2007) in groups that are actively cultivating seaweed in Akle. Primary data from cultivation experiments were collected from April to October 2021 to observe growth, analyze carrageenan and nutrients of K. alvarezii. (Figure 1)Description of the study sites.

Data Analysis

(a) The specific growth rate (SGR) is calculated based on the formula proposed by Dawes,et al (1994):

$$SGR = \frac{LnWt – LnWo}{\mathrm{t}} x100\%$$

SGR : the specific growth rate (g% day^{-1})

W_t : final weights (g)

Wo : initial weight g)

t : observation (day)
(b) Carrageenan content (CC) : The carrageenan content (%) was determined according to the formula:

CC : We (g) / Ws (g) X 100% (FMC Corp, 1977)

where We is the extracted carrageenan weight (g) and Ws is sample weight (g) used for extraction. The data are presented as the mean yield obtained from three replicates

Carrageenan Extraction

The isolation method of carrageenan from seaweed Kappaphycus alvarezii was optimized by varying the potassium hydroxide (KOH). Where dried K.alvarezii were washed with tap water to eliminate sand, debris and epiphytes, than dried K. alvarezii was cut into small pieces (± 1 cm), and then weighed as much as 100 grams. Dried *K.alvarezii* (100 g) were incubated in 1000 mL 6% KOH at 90°C for 2 hour.Then, it was extracted using KOH with the ratio of seaweed to the solvent 1:20 (g/mL). The extraction was done using a hot plate at 90^0 C. Furthermore, it was filtered using a gauze when it was still hot.

(c) Nutrition analysis of carrageenan refers to the AOAC (2005). This research is based on descriptive and quantitative analysis methods used to determine growth, carrageenan content, protein, fat, carbohydrate, moisture, ash and crude.

Results

Correlation between Temperature, salinity and Growth of Kappapyhcus at Akle waters

a.Specific Growth Rate (SGR)

The average SGR during different water temperatures showed that at 29 ^{0}C the SGR was 6.25%, at temperature 30^0C the SGR was 5.19%, at temperature 31^0C (4.63%), at temperature 33^0C the SGR 2.41%, 34^0C the SGR 2,08, and 35^0C the SGR was 1.90%. Results showed that *K. alvarezii* had a higher specific growth rate at higher temperature (29 ^{0} C – 31°C). We observed that at a temperature range from 29 to 31 ^{0}C the *K.alvarezii* was not affected by ice-ice; however, at temperatures 33 to 35 ^{0}C, the incidence of ice-ice disease was present (Fig. 2a, 2b).

Figure 2a, 2b shows that there is a correlation between temperature and specific growth of *K. alvarezii* during the 45 day culture period with values (6.25–3.60%) from March to October and lower values (1.9–2.08%) from November to January. A significant difference was found ($p < 0.05$) where the results of the analysis of variance had a significant effect on the growth of K. alvarezii seaweed. The results of the Tukey's test showed that the treatment temperature of 29 ^{0}C was significantly different from the treatment at 30 ^{0} C, 32^0C, 33^0C, 34 ^{0}C and 35 ^{0}C. While the temperature of 30 ^{0}C was not significantly different from the temperature of 31 ^{0}C. The difference in the average specific growth of *K. alvarezii* seaweed at each temperature change, salinity was thought to be due to the influence of temperature and salinity on enzyme activity. The content of nutrients that are responded to by seaweed according to changes in temperature, the higher the temperature, the enzymes do not work properly, besides that it is also influenced by the different ecological characteristics of the waters, which is one of the factors for the difference in absolute average growth at each change in temperature and salinity (Sarojini & Sujata, 2015)

Carrageenan Content

In this research, carrageenan had the highest protein content (5.03% – 5.16%), carbohydrate (67.07%-70.48%) and fat (3.38% – 3.67%) to temperature (29 ^{0} C-31^0C), but the moisture content, ash content and crude fiber was lower than at temperature (32–34) and salinity (33–35 psu). (Table 1.)

Table 1
Carrageenan and nutrition content of *K.alvarezii*

Temperature (^0C)	Month	Carrageenan (%)	Nutrition (%)					
			Protein	fat	carbohidrate	moisture	ash	crude
29–30	Mar-Apr	65.43	5.16	3.67	70.48	10.07	9.46	1.16
30–31	May - Jun	65.16	5.03	3.38	67.07	11.02	11.47	2.03
31–32	Jul - Aug	41.87	4.89	2.46	50.18	25.19	15.13	2.15
32–33	Sep - Oct	25.20	4.06	2.03	40.15	35.53	15.58	2.65
33–34	Nov - Dec	18.26	2.17	1.39	31.60	41.42	19.05	4.37
34–35	Dec - Jan	7.27	1.26	1.36	27.75	45.58	19.68	4.84

Table 1, showed that the carrageenan and nutrient content of K. alvarezii seaweed at a temperature of 29 ^{0}C -32^{0}C di bulan Maret – Juli sebesar 41.87% − 65.43%. The average water content of the resulting carrageenan ranged from 10.07% -11.02% and the analysis results were thought to be influenced by KOH. So the lower the water content of carrageenan, this is thought to be caused by the ability of KOH to extract and inhibit the increase in water in the *K. alvarezii* seaweed molecules so that the water content decreases. The results of this study are in line with Anwar et al. (2013) that the decrease in the water content of is due to the alkaline atmosphere of the KOH solution which is able to inhibit the occurrence of an increase in water in the alginate molecule, so used of KOH can reduce the mineral salts contained therein. The results showed that there was a relationship between the content of carrageenan, nutrition with temperature and salinity. Where the higher the temperature and salinity, the lower the carrageenan and nutrient content, this is shows the influence of environmental factors. Carrageenan and chemical nutrition affected by different temperature and salinity. Carrageenan and nutrition show variations in the nutritional content related to environmental factors seaweed growing waters. The quantity of carrageenan is affected by environmental factors. The salinity, temperature, nutrients and intense irradiance causes high rate of growth (Zucchi and Necchi 2001). The positive correlation may be due to higher biomass and nutrients in water (Li et al, 2019). As described by Benjama and Mashiyom, (2012) that nutrient composition of seaweed was different and affected by geographical area, species and environmental growth condition. As described by Matanjun et al.(2009) that variations in the protein content of seaweeds can occur due to different species and season

Morphological features

Different water temperatures change the appearance of the thallus and branching of the seaweed. At temperature 29-31^{0}C the appearance of seaweed is fresher, and more branches appear in the thallus (Fig. 3) compared to the less morphological features of the seaweed at higher temperatures (Fig. 4).

Discussion

Temperature and salinity are well-known environmental factors that affect the growth and carrageenan content of *Kappaphycus alvarezii* (Lobban, et al. 1994). In addition, this is also due to the fact that seaweed at a temperature of 29 ^{0}C-31^{0}C and salinity of 30–31 psu is protected from exposure to sunlight which has a negative impact, namely ultra violet radiation on the carrageenan content of seaweed. According to Oedjoe et al (2020), the quantity and quality of carrageenan produced from mariculture because difference sunlight intensity, temperature, nutrients, and salinity. The difference in average growth of *K. alvarezii* seaweed at each temperature change was thought to be due to the effect of temperature on enzyme activity. Hung, et al (2019) explain that the content of nutrients that are responded to by seaweed according to changes in temperature, the higher the temperature, the enzymes do not work properly, besides that it is also influenced by the different ecological characteristics of the waters, which is one of the factors for the difference in average growth at each temperature change. According to Fikri et al (2015) that seaweed is a plant which in its metabolic process requires the suitability of physical and chemical factors of the waters such as water movement, temperature, salt content, nutrients or nutrients (such as nitrate and phosphate), and light lighting. The low growth of seaweed at a temperature of 34 ^{0}C-35 ^{0}C is suspected because the water is clean with nutrients, besides that at a temperature of 34 ^{0} C-35^0 C the evaporation is high. While Parenrengi et al. (2010) stated that currents carrying solid particles that will stick to the seaweed thallus will interfere with the photosynthesis process. According to Raikar et al (2001), seaweed is strongly influenced by water conditions such as: waves are needed by seaweed to accelerate nutrients into plant cells, While Pong-Masak & Sarira (2018) explained that currents are needed for growth because currents can carry nutrients for seaweed and wash away dirts attached to seaweed, so that seaweed that gets a large supply of nutrients or food will accelerate its growth. The content of nutrients that are responded to by seaweed according to changes in temperature, the higher the temperature, the enzymes do not work properly, besides that it is also influenced by the different ecological characteristics of the waters, which is one of the factors for the difference in average growth at each temperature change (Gerung & Ohno ,1997)

Carrageenan Content

Table 1, showed the chemical nutrition of Carrageenan product that was processed from temperatue and salinity from waters Akle. The carrageenan showed variation in the nutrient content which were related to environmental parameters where seaweed growth (Dewi et al, 2018). As described by Manuhara, et al. (2016) that the nutrition composition can be influenced by the growing parameters (water temperature, salinity, light and nitrate as a nutrient compound), since macroalgae can be considered bioreactor that may able to provide different polysaccharides at different quantity (Manivannan, et.al 2009). Reaffirmed by Periyasamy et al (2016) that carrageenan and chemical nutrition affected by different temperature and salinity. carrageenan and nutrition quality were affected by the growth of hydrocolloid compound in the thallus, where the growths of thallus were influenced by nitrates compound (Matanjun, et al, 2009). Nitrates were carried into the thallus cells by the use of nitrate reductase and was transformed into nitrites (Silkin,et al. 2014). Carrageenan and nutrition show variations in the nutritional content related to environmental factors seaweed growing waters (Wenno et al, 2012). As stated by (Zucchi and Necchi 2001., Paula,et al,2002.) the quantity and quality of carrageenan produced from marine culture varies due to differences in varieties or species, planting age, sunlight intensity, temperature, nutrition, and salinity. Supported by (Hayashi, et al 2007) that the quantity of carrageenan is affected by environmental factors. The salinity, temperature, nutrients and intense irradiance causes high rate of growth. The positive correlation may be due to higher biomass and nutrients in water (Li et al, 2019). The moisture content is an important criterion in determining the quality and shelf-life of processed seaweed meals where high moisture may hasten the growth of microorganisms (Rohani et al., 2012).

Water Temperature

The results explain that temperature and salinity influence production and growth. The water temperature observed during the study was from 29 ^{0}C to 35 ^{0}C. At water temperature 29 ^{0}C to 31 ^{0}C the growth of *K.alvarezii* was not affected by ice-ice disease, while there was ice-ice disease at water temperature 32^{0}C – 35 ^{0}C. Temperature ranges from 29 ^{0}C to 31 ^{0}C is very supportive to the growth and production of seaweed. According to Radiarta et al., (2013), the water temperature that supports the growth of seaweed is from 29 ^{0}C to 31 ^{0}C. Temperature and salinity affect the life of biota as they relate to the level of oxygen solubility, the respiration process of aquatic biota, and the rate of degradation of pollutants (Amin et al., 2005). It was also supported by Nur et al (2016) which mentioned that temperature, salinity, turbidity, pH, and dissolved oxygen affect the growth and production. Seaweeds are found in a wide range of teremperature and salinity therefore Seaweeds can live in the littoral and sublittoral zone. Seaweeds are protists and are protected by a layer, which protects them from harmful salinity and acidification of the sea Li et al, (2019). The temperature primarily controls the biogeography of seaweed specie. Mudeng et al (2015) Seawater temperature has been increasing annually due to the global warming, which is directly related to the amount of light reaching the sea. These climate changes have caused measurable effects on thallus near their thermal limit, whereas blades may decay or even drop away from floating twines. The temperature can also affect reproduction through its effects on metabolism rates. The reproduction and sorus induction time, and the enhancement of the reproductive traits are dependent from temperature, being a few examples within the brown seaweed (Marinho-Soriano, et al 2006. Abdullah, et al 2020.). Temperature also affects the morphology of the seaweed. Neksidin et al. (2013) explained that the different temperatures will affect the growth and production of seaweed both morphologically and physiologically (Figs. 4 and 5 shown the different responses to temperatures changes). Additionally, Choi et al. (2010) argue that temperature has a significant role in the growth, callus formation, and morphogenetic development of seaweed because of osmoregulation events in cells. They argue that different fluid concentrations between the inside and outside cells encourage the cell's Golgi apparatus to keep trying to balance until it becomes isotonic. As a result, this has an impact on greater energy utilization so that it affects the low growth and development of seaweed (Xiong and Zhu, 2002). At high temperatures, water inside of cells seaweed was lower or shrinking, which is an indication of a hypertonic event resulting from the concentration of the water fluid being more concentrated than the concentration of fluid in the seaweed cells. According to Choi et al. (2010), a more concentrated external environment causes the fluid to flow out. The cell then size decreases as it undergoes plasmolysis, marked by the membrane release from the wall. Xiong and Zhu (2002), Oedjoe et al. (2020) explain that temperature on plants is very complex, such as ionic stress, osmotic stress, and secondary stress. Ion stress due to high-temperature results in Na^+ poisoning. Excessive Na^+ ions on the thallus surface can inhibit K^+ uptake from the environment, even though K^+ ions play a role in maintaining cell flaccid and enzyme activity. Meanwhile, osmotic stress caused by an increase in temperature which affects the high osmotic pressure so that it inhibits the absorption of water and the elements that take place through the osmosis process. If the amount of water that enters the cell is reduced, it will reduce the amount of water supply in the cell (Choi et al., 2010 Akib et al. (2015) explained that temperature affects plant growth and development; Andi *et al*. (2016) also discussed further that temperature affects metabolism, photosynthesis, respiration, and plant transpiration. High temperatures on 33 ^{0}C to 35 ^{0}C can damage the enzymes so that metabolism does not work well, as well as low temperatures can cause enzymes to be inactive and metabolism to stop (Yoppy *et al*., 2015) (as shown in Fig. 5).This is due to the number of cells at high temperatures (> 34 ^{0}C) is lower than it is in 29 ^{0}C-30 ^{0}C. Many cells are damaged due to the concentration of media that is too concentrated (hypertonic). According to Amri & Arifin (2016) if the temperature range has exceeded the life span of algae, the growth and development of algal cells is linear and inversely (negative) with an increase in temperature and salinity. High temperature affects the growth and structural changes of algae, among others, the smaller size of the stomata, so that the absorption of nutrients and water is reduced, ultimately inhibiting algae growth at the level of organs, tissues and cells. The impact of temperature changes that are too high or low causes an increase in pressure for aquaculture, including seaweed farming (Sofri et al., 2018). According to Apriyana (2006), the enzymes in *K. alvarezii* cannot function at temperatures that are too hot or too cold. Supported by Mudeng & Ngangi (2014), that seaweed has a specific temperature range due to the presence of enzymes in seaweed that cannot function at temperatures that are too cold or too hot. High water temperatures affect the rate of photosynthesis and can damage enzymes and cell membranes which are unstable. At low temperatures, membrane proteins and fats can be damaged as a result of the formation of crystals in cells, thus affecting seaweed life, such as loss of life, growth and development, reproduction, photosynthesis, and respiration (Kumar et al, 2020). The impact of rising sea water temperatures clearly influences seaweed production compared to the optimum temperatures around 29 ^{0}C to 31 ^{0}C (Oedjoe et al., 2020).

Salinity

Each marine organism has a different tolerance range to salinity, including *K. alvarezii*. Therefore, salinity is one of the key factors affecting organisms' survival and growth (Choi et al., 2010). The results of salinity measurements during the study ranged from 30 to 36 psut. Pongarrang et al. (2013) stated that *K. alvarezii* is a seaweed that cannot withstand a range of high salinity (stenohaline). The salt content that is suitable for growth ranges from 28 to 35 psu Meanwhile, according to Ding et al (2013) the range of seaweed growth can thrive in tropical areas with a water salinity of 32 to 34 psu. Changes in temperature can increase changes in salinity, resulting in physiological stresses on aquatic organisms and affect productivity and also increase disease susceptibility (Radiarta et al., 2013). As also supported by Amin et al. (2005), explaining that coastal waters are most easily affected by changes in temperature and salinity. In addition, it also affects temperature and salinity; it can cause bleaching seaweed disease (ice-ice) and will impact seaweed production (as the enzymes' work in forming new cells is disrupted, as shown in Fig. 4).

Conclusion

K. alvarezii that was cultivated for six weeks at the temperature range from 29 ^{0}C to 31 ^{0}C with 30 to 31 psu salinity range was specific growth rate 5.19%day^{-1} to 6.25% day^{-1} of seaweed, while the carrageenan content 65.16%-65.42% to March to June with no appearance of the ice-ice disease. whereas the higher the temperatures, the lower the growth rate, carrageenan and nutristion of kappaphycus alvarezii

Declarations

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Availability of data upon reasonable request, the data sets of this study can be available from the corresponding author.

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Figures

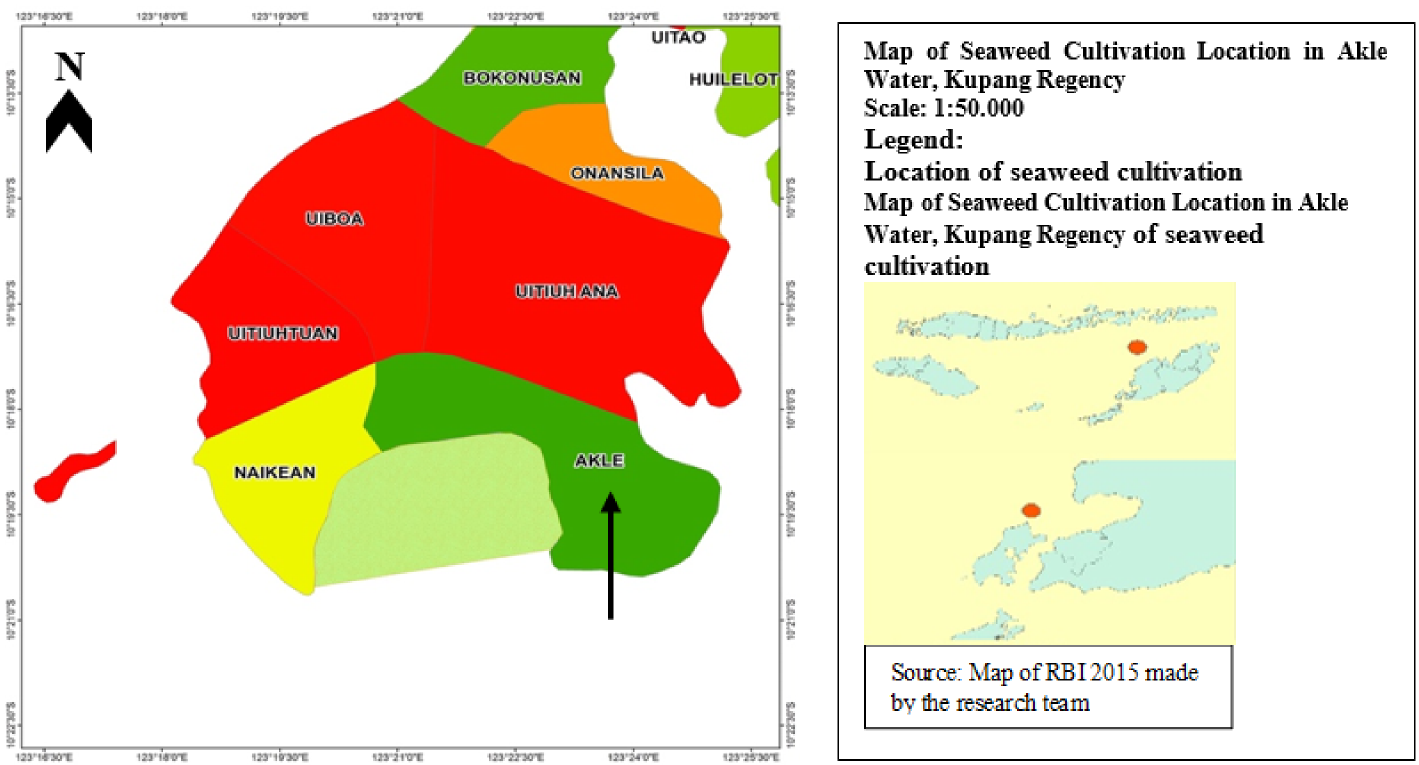
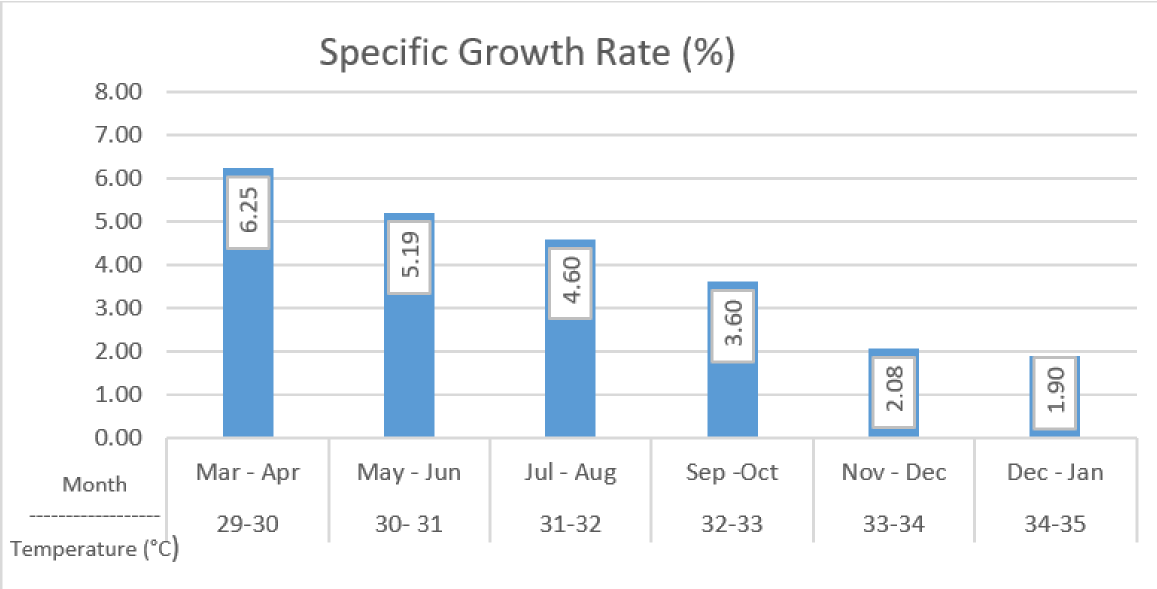
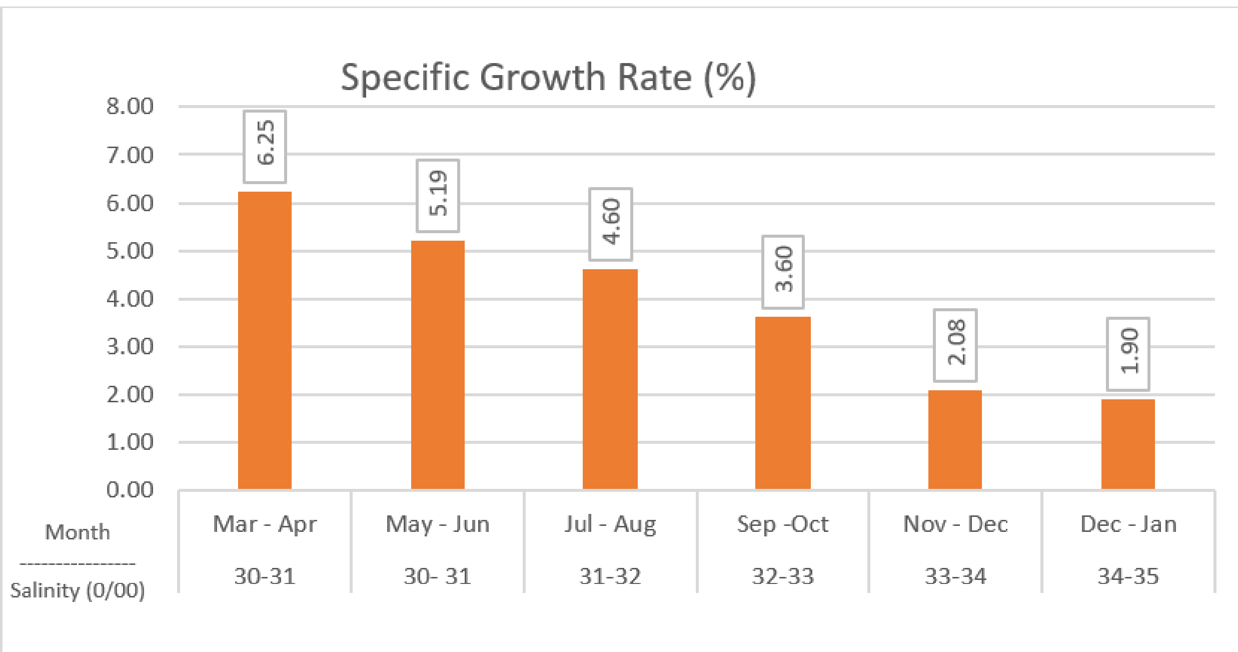


Figure 1

Location of Akle Water Research



A



B

Figure 2

a Correlation temperature & spesific growth rate (%) of *Kappaphycus alvarezii* over a 45-day culture period

b Correlation salinity & spesific growth rate (%) of *Kappaphycus alvarezii* over a 45-day culture period

Figure 3

Condition of *K.alvarezii* at temperature 29 to 31 ^{0} C, salinity 30 to 31 psu at Akle Waters on March to June

(a) 32^{0}C at July (b) 33^{0}C at August (c) 34^{0}C at September (d) 35^{0} C at October

Figure 4

Condition of *K. alvarezii* at Temperature 32^{0}C and salinity 33psu; 33^{0}C and 34psu; 34^{0}C and 35psu; 35^{0} C and 35 psu during cultivation

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