2. Untuk menghasilkan kandungan karaginan tertinggi pada K. alvarezii strain hijau, sebaiknya dilakukan budidaya pada peralihan musim dari musim hujan ke musim kemarau di inshore dan offshore, sedangkan strain coklat pada musim kemarau di inshore dan peralihan musim dari hujan ke musim kemarau di offshore.
3. Untuk mendapatkan kandungan karotenoid tertinggi pada K. alvarezii strain hijau, sebaiknya dilakukan budidaya pada peralihan musim dari musim hujan ke musim kemarau di inshore, sedangkan strain coklat pada peralihan musim dari hujan ke musim kemarau di inshore dan offshore.
4. Untuk mendapatkan kekuatan gel tertinggi pada K. alvarezii strain hijau, sebaiknya dilakukan budidaya pada peralihan musim dari musim hujan ke musim kemarau di offshore dan musim kemarau di inshore, sedangkan strain coklat pada peralihan musim dari hujan ke musim kemarau dan musim kemarau di inshore.
5. Untuk mendapatkan viscositas tertinggi pada K. alvarezii strain hijau, sebaiknya dilakukan budidaya pada musim kemarau di inshore dan offshore, sedangkan strain coklat pada peralihan musim dari hujan ke musim kemarau dan musim kemarau di inshore.
6. Pertumbuhan gulma dari spesies sargassum, gracillaria, ulva, dan hypnea terjadi pada peralihan musim dari musim hujan ke musim kemarau di inshore dan offshore, musim kemarau di offshore dan pada peralihan musim dari usim kemarau ke musim hujan. Pada musim-musim tersebut sebaiknya dilakukan pengontrolan yang maksimal untuk meminimalisir adanya gulma yang mengganggu pertumbuhan K.alvarezii baik strain hijau maupun coklat.
7. Keberadaan epifit dan penyakit pada kegiatan budidaya terpantau pada musim kemarau baik di inshore maupun di offshore, maka disarankan pada musim-musim tersebut kegiatan budidaya rumput laut sebaiknya dihindari atau tidak dilakukan samasekali untuk mengantisipasi kerugian bagi petani rumput laut.

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WEEDS, EPIPHYTES AND ICE-ICE DISEASE ON GREEN-STRAINED *KAPPAPHYCUS ALVAREZII* (DOTY) IN TAKALAR WATERS, SOUTH SULAWESI IN DIFFERENT SEASONS AND LOCATIONS OF CULTIVATION

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Abstract

Weeds, epiphytes, and ice-ice damage the *Kappaphycus alvarezii* seaweed system is often found at cultivation sites, impacting on yields. The location of cultivation that has a problem of weeds, epiphytes and ice-ice is Takalar District, a production centre in South Sulawesi, often encountered in extreme weather and not in optimal environmental quality. This study was carried out to analyze weed density, epiphytic attachment, and infection of ice-ice disease of green-strained *K. alvarezii* seaweed in different seasons and locations of cultivation. This research was conducted in the waters of Punaga Village, Takalar Regency in two locations, that were inshore and offshore, using the long line method, which was 45 days for each location. Weeds, epiphytes and ice-ice diseases and water quality were observed by season and location and analyzed descriptively. The results showed that the season affected weed density, epiphytic attachment and ice-ice infection. In the transition season from the rainy season to the dry season (May-July), weeds of the *Hypnea* sp type dominated the seaweed cultivation area (137.5g / m), the beginning of the dry season (May-July) *Sargassum* sp. (431.25g / m) and *Ulva* sp. (137.5g / m) appeared on offshore, but none on inshore. Epiphytes Neosiphonia sp. and ice-ice disease infect the thallus at the end of the dry season (September-October) onshore and offshore.

***Keyword*:** Epiphyte; ice-ice; inshore; *Kappaphycus* sp.; offshore; season; weed.

Introduction

Green-strained *Kappaphycus alvarezii* (Doty) is one seaweed type that produces kappa-carrageenan which is widely cultivated and used as the main livelihood in some coastal communities in Indonesia. Seaweed production fluctuates according to season, generally the productive season is from April to October, while the less productive planting season is in January, November, and December. The pattern of seaweed production changes based on climate, where climate influences the condition of local waters (Arisandi *et al.*, 2013; Asni, 2015).

In certain seasons *K. alvarezii* has decreased biomass due to damage to the thallus. This is caused by several factors, and what is commonly found in seaweed farming activities is the presence of weeds, epiphytes, and ice-ice disease. The impact of these three factors varies on seaweed. Weed is a competitor in terms of absorption of nutrients and barrier to sun penetration that can inhibit photosynthesis (Arisandi *et al.*, 2017; Gazali *et al.*, 2018; and Joppy, 2014), but on the other hand, weeds function as shelters from pest attacks.

In addition to weeds, a factor causing the decline in seaweed production is epiphytes, which their presence is influenced by seasons, as occurs in several countries such as Sabah, Malaysia and the Philippines (Vairappan *et al.*, 2008), the emergence of epiphytes that infect *K. alvarezii* in general from the macroalga group like *Neosiphonia spp.* (Vairappan *et al.*, 2008) whose existence is related to changes in water quality such as temperature and salinity.

In contrast to weeds and epiphytes, ice-ice disease infection in seaweed is characterized by a change in the color of the talus to turn pale yellow and eventually turn white and break easily (Maryunus, 2018).

Based on the description above about weed density, epiphytic attachment and infectious diseases in seaweed affected by the season, and the season will affect water quality, then a study was conducted to analyse the presence of weeds, epiphytes, and ice-ice disease of *K. alvarezii* seaweed in green waters in different seasons and locations.

Materials and Methods

The research was carried out for a year in different locations and seasons from April 2018 to March 2019, in Malelaya Hamlet waters, Punaga Kecamatan Mangarabombang Village, Takalar Regency, South Sulawesi Province. To obtain research samples, seaweed planting was carried out on a stretch rope by following the planting pattern according to the season at different cultivation locations. All cultivation periods were carried out for 45 days. Seaweed was cultivated in two different waters locations in waters close to the coast (inshore) and in waters that has a steep slope (offshore). Seaweed cultivation was done by the long line method (Kasim & Mustafa, 2017). The seaweed planting patterns were based on different seasons, that were the transition from the rainy season to the dry season (April-May), the beginning of the dry season (May-June), mid-dry season (July-August), end of the dry season (September-October), transition from the dry season to the rainy season (October-November). In the rainy season (December-March) planting was not carried out because the weather conditions do not allow planting, and even local farmers did not carry out cultivation activities. During the study period, we collected data on weed density, epiphytic attachment, and ice-ice infection in seaweed and recording of water quality parameters according to the seaweed planting period in different seasons and locations.

Weed density calculation was done at the end of maintenance along with the seaweed harvest time. Weeds that grow on a stretch of rope along with seaweed were separated by type, then weighed as a whole. Determination of weed density is calculated by the formula cited in (Hendrawati, 2018) as follows: K = *ni* / A, where, K is weed species density (ind/m), *ni* is the number of species (individuals) and A is the length of the stretch (m). Meanwhile, to find out the epiphyte and ice-ice disease on seaweed thallus, its samples were randomly taken, put in sterile plastic bags, placed in a coolbox at a temperature of less than 4 degrees Celsius, then taken to the laboratory for analysis.

The water quality parameters observed in situ are physical parameters including temperature measured with a thermometer, salinity with a refractometer, and a flow meter to measure the speed of the current. While the chemical parameters measured are parameters that support the growth of seaweed such as NO_3, PO_4, CO_2, Ca and Mg analyzed in the laboratory by spectrophotometry based on the method (Parsoons, 1972).

Statistical Analysis

Data on the density of weeds that grow on the stretch of seaweed culture, epiphytic attachment to the seaweed thallus, and ice-ice disease that infects seaweed were analysed descriptively. While the water quality data measured both insitu and in the laboratory were also analyzed descriptively.

Results

Weeds in the cultivation of green-strained seaweed K. Alvarezii on Inshore and Offshore at Different Seasons

There are 4 (four) species weeds that dominate the green-strained K. Alvarezii seaweed, that are Ulva sp., Sargassum sp., Gracillaria sp., And Hypnea sp. (Figure 1). Weeds attached to the seaweed thallus vary according to season and location of cultivation, both density, and species (Figure 1).

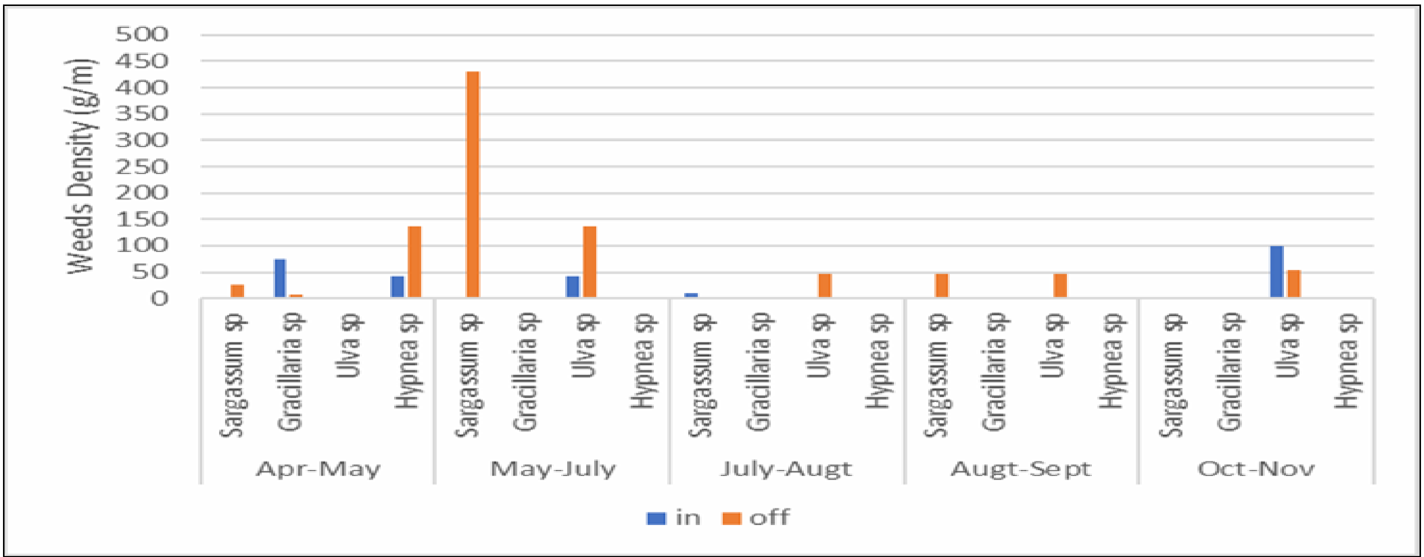

Fig. 1 : Density of weeds on *K. Alvarezii* seaweed at different locations and seasons

The presence of weeds at the study site was detected in the transition season from the rainy season to the dry season (April-May), dominated by *Gracillaria sp.* (75g/m) inshore and *Hypnea sp.* (137.5 g/m) offshore, at the beginning of the dry season (May-July) was dominated by *Sargassum sp.* (431.25g/m) and followed by *Ulva sp* (137.5g/m) offshore. Furthermore, in the middle of the dry season (July-Aug) until the end of the dry season, *Ulva sp.* appeared attached to the stretch of seaweed cultivation only offshore, and entered the transition season or transition season from the dry season to the rainy season (Oct-Nov), the existence of *Ulva* sp. was seen both onshore and offshore.

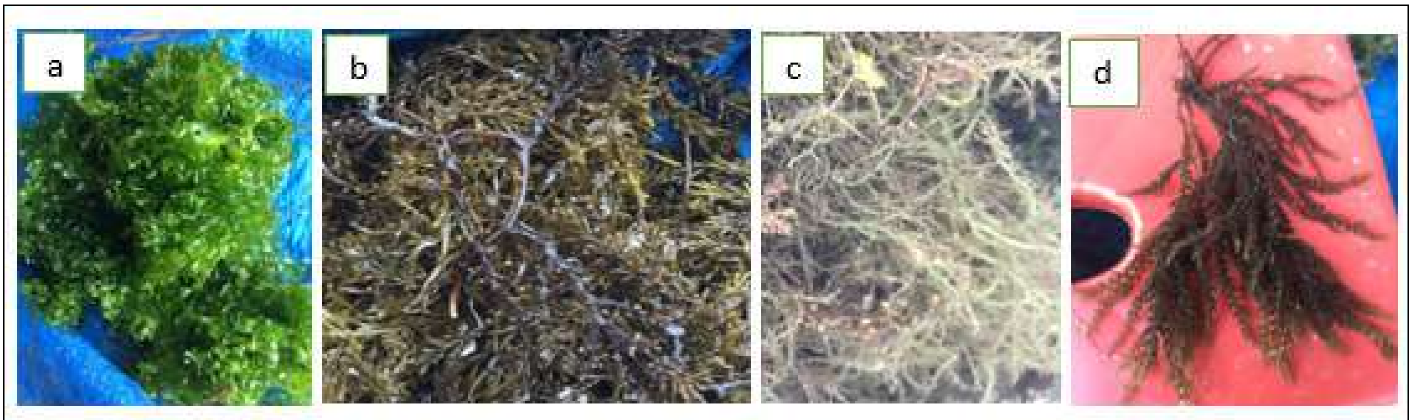

Fig. 2 : Types of weeds in seaweed, (a) *Ulva* sp., (b) *Sargassum* sp., (c) *Gracillaria* sp., and (d) *Hypnea* sp

Epiphytes on seaweed Green-Strained Kappaphycus alvarezii on Inshore and Offshore at Different Seasons

Epiphytes attached to seaweed during the study were seen at the end of the dry season (Sept-Oct), both onshore and offshore. The epiphytes were found from the *Neosiphonia sp.* type which attached to the surface of the seaweed species *K. Alvarezii*. The observation of several thallus taken at random shows small black spots that gather in a circle, a thallus surface that contains a lot of mucus, and fine threads (Figure 3).

Fig. 3 : Epiphytes attached to the seaweed thallus, (a) black spots, (b) Mucus and (c) Fine threads

Infection of Ice-Ice Disease in Green-Strained Kappaphycus alvarezii on Inshore and Offshore at Different Season

The infection of Ice-ice disease during the study occurred at the end of the dry season (Sept-Oct), both onshore and offshore. Seaweed infected with ice-ice has a change in the color of its thallus from green to yellowish and eventually turned to white and destroyed. This change starts from the epical part towards the basal part of the seaweed thallus (Figure 4).

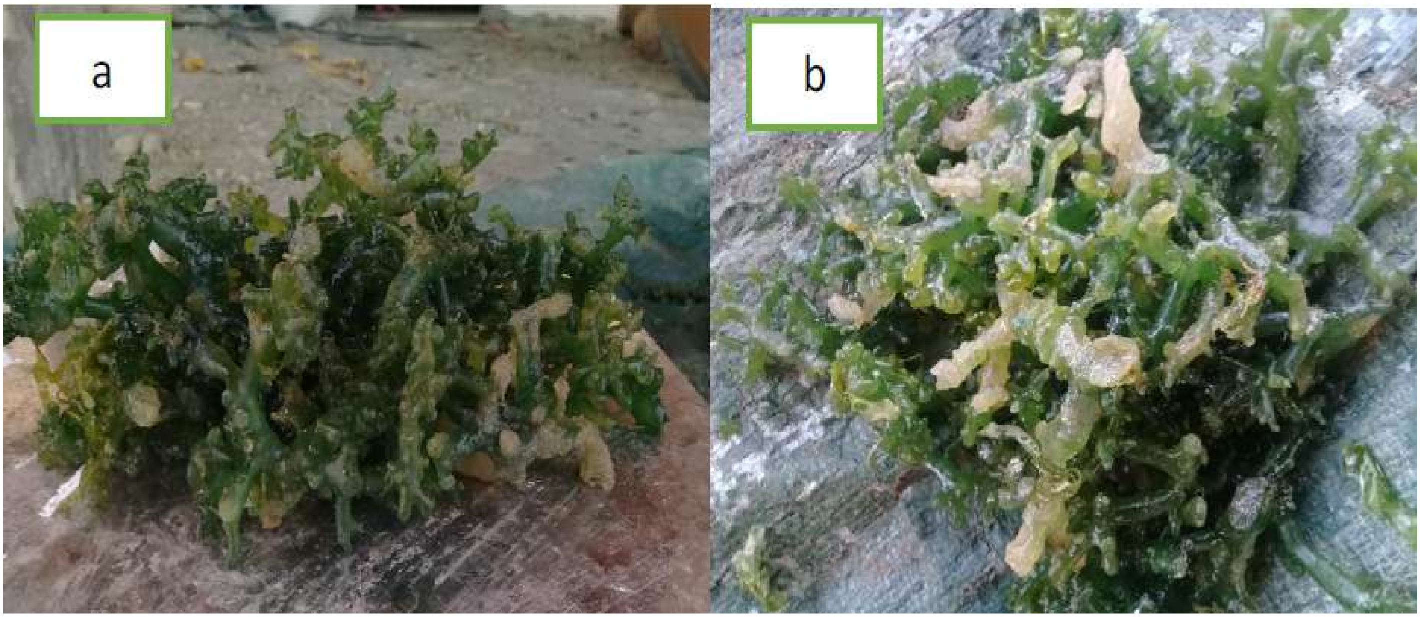

Fig. 4 : Ice-Ice Disease on seaweed thallus, (a) inshore, (b) offshore

Water Quality

Water quality parameters observed during the study were temperature, salinity, pH, brightness, current speed, PO_4, NO_3, CO_2, Ca and Mg. Each concentration value of the parameter shows a different state of concentrations, depending on the season and location of cultivation and has an impact on the presence of weeds, epiphytic attachment or infection with ice-disease (Tables 1 and 2).

Table 1 : Concentrations of Temperature, Salinity, Brightness, pH and Flow Speed in Different

Parameters	Units	Locations	Seasons					Optimum ranges	Reference
			I	II	III	IV	V		
Temperature	°C	inshore	28.5-30.5	30.0-31.0	30.0-31.5	30.0-31.0	29.0-30.5	20 – 28	Parenrengi, 2012.
								24-27	Radiarta, 2016.
		offshore	29.0-31.0	30.0-31.5	30.1-31.5	30.5-31.1	30.0-31.1	24-30	Largo, 2020
salinity	ppt	inshore	33.9-35.1	34.5-35.0	33.5-35.5	33.0-34.0	31.1-33.0	28-34	Largo, 2017
		offshore	33.5-35.5	35.0-35.5	33.9-35.0	33.0-34.5	31.5-33.0	30-33	Hurtado, 2017
Brightness	%	inshore	100	100	100	100	100	100	Lideman, 2013
		offshore	100	100	100	100	100		
pH	-	inshore	7.53-7.64	7.53-8.3	7.65-8.2	7.9-8.0	7.53-8.1	06-Sep	Zitta, 2012
		offshore	7.83-7.97	7.89-7.97	7.89-8.1	7.5-7.9	7.53-7.9		
Current speed	cm/det	inshore	5.8-6.5	4.5-6.5	4.5-5.5	4.0-5.5	5.5-6.46	6-46.9	Sulistiawati, 2020
		offshore	6.5-7.5	5.0-6.5	5.4-6.8	6.5-7.5	7.8-8.5		

Notes:
I = Transition season from the rainy season to the dry season (April-May)
II = Beginning of the Dry season (May-July)
III = Mid-Dry Season (July-August)
IV = End of the Dry Season (September-October)
V = Transition Season from Dry Season to Rainy Season (October-November)

Observation of water temperature shows that the temperature in the dry season is higher than the temperature in the transition season, both on land and offshore. Temperatures in the transition season from the wet season to the dry season on land and offshore (29-31°C and 30-31.1°C), the dry season (30-31°C and 30-31.5°C) and in the transition season from the dry season to the rainy season (28.5-30.5°C and 29-30.5°C). The suitable temperature for the cultivation of *K. alvarezii* according to (Radiarta *et al*., 2016; Syamsuddin and Rahman, 2014) is 24-27°C and 25-26°C, if an increase in temperature occurs, it will affect on the discoloration of thallus seaweed, becoming yellowish, not growing optimally, and will provide opportunities for epiphytes to grow.

For salinity parameters, in all seasons both inshore and offshore shows an appropriate value of salinity for seaweed cultivation (Hurtado *et al*., 2017). Brightness parameter is a requirement for the continuation of the photosynthesis process and in this study in different seasons and locations, the brightness at all the cultivation site supports the photosynthesis process, which is at 100%, while the pH and current speed are all in accordance with the growing needs of *K. alvaezii* (Zitta *et al*., 2012 and Sulistiawati *et al*., 2020).

Table 2 : Concentrations of PO_4, NO_3, CO_2, Ca and Mg in Different Seasons and Locations

Parameters	Units	Locations	Seasons					Optimum ranges	Parameters
			I	II	III	IV	V		
PO_4	ppm	inshore	0.5-0.71	0.2-0.4	0.4-0.49	0.49-0.60	0.5-0.72	0.37-0.5	Pariakan *et al*., 2019
		offshore	0.6-0.72	0.2-0.4	0.4-0.69	0.69-0.72	0.71-0.78		Akmal *et al*., 2017 Gunalan *et al*., 2010
NO_3	ppm	inshore	0.4-0.46	0.19-0.25	0.15-0.25	0.15-0.27	0.43-0.5	0.6 – 0.37	Mustafa *et al*., 2017
		offshore	0.2-0.58	0.1-0.2	0.1-0.2	0.15-0.2	0.35-0.41		
CO_2	ppm	inshore	15.34-22.76	22.76-29.97	27-95-29.97	25-96-27.95	22.50-25.96	23-25	Triyulianti *et al*., 2018
		offshore	23.95-28.45	21.97-28.45	21.97-31.96	31.95-31.96	28.45-31.95	34-58	Akmal *et al*., 2017b
Ca	ppm	inshore	920-1023	920-1041	1041-1282	1281-2403	1023-2403	422	Tucker, 1998
		offshore	920-1024	920-1041	1041-1401	1401-2121	1024-2121		
Mg	ppm	inshore	4861-4909	4861-5637	3020-5637	3020-3911	3911-4681	1324	
		offshore	4822-4884	4822-5504	2634-5504	2634-3707	3707-4822		

Notes:
I = Transition season from the rainy season to the dry season (April-May)
II = Beginning of the Dry season (May-July)
III = Mid-Dry Season (July-August)
IV = End of the Dry Season (September-October)
V = Transition Season from Dry Season to Rainy Season (October-November)

Chemical parameters, such as PO_4, show higher concentrations offshore at the end of the dry season and in the transition season from the dry season to the rainy season, which are 0.69 to 0.72 and 0.71 to 0.78 ppm, while the feasibility value for seaweed are 0.37-0.5 (Pariakan *et al*., 2019) and 0.064-0.599 ppm (Akmal *et al*., 2017). For NO_3 parameters, waters that support seaweed growth are waters that has NO_3 content of 0.6 -3.7 ppm (Mustafa *et al*., 2017), while the results of NO_3 measurements at the study sites in different seasons both inshore and offshore respectively 0.15-0.46 ppm and 0.1-0.58 ppm respectively. The CO_2 parameter shows that the concentration in the offshore is in a reasonable range except at the end of the dry season and the transition to the dry season during the rainy season, the concentration is higher than the feasibility limit according to (Triyulianti *et al*., 2018). CO_2 with a range of 29.2-39.3 ppm is an appropriate range for the cultivation of *E. cottonii* (Akmal *et al*., 2017). While the parameters of Ca and Mg are in a range that is suitable for the growth of *K. alvarezii* seaweed (Tucker, 1998).

Discussion

Weeds

Weeds or disruptive plants (seaweed) are often found on stretch cords and cover seaweed thallus, and seaweed farmers have difficulty coping so that impacts on the quality and quantity of the harvest. Weeds that covered the seaweed talus during the study of *Ulva sp*., *Sargassum sp*., *Gracillaria sp*., and *Hypnea sp*., and seen *Sargassum sp* dominate with density (431.25g/m) at the beginning of the dry season in May-July offshore. Besides the prolonged high temperatures (30-31.5^{o}C), the high density of *Sargassum sp.* in early summer is caused by *Sargassum sp.* being perennial or its presence based on the season, that is in the west and east seasons (Kadi, 2005). Furthermore, it is said that *Sargassum sp.* grows well in coastal areas with large waves and heavy currents depth of 0.5-10 m, and offshore is a suitable habitat for *Sargassum sp.* (Rama *et al*., 2018)

Epiphyte

The existence of epiphytes is strongly influenced by the lack of availability of nutrients and extreme weather phenomena that have an impact on drastic changes in water quality parameters (Maryunus, 2018). The low nitrate content at the peak and the end of the dry season (0.1-0.2 ppm) and the high temperature and salinity (30-31.5^{o}C and 33-35%) are the cause of the decline in seaweed immunity. Another impact of extreme weather on seaweed is the release of spores from cystocarp (Harwinda *et al*., 2018). This cystocarp hole will be covered by mucus as a form of self-defense of seaweed, on the other hand, mucus, and this is a good growing medium for epiphytes and bacteria that cause ice-ice disease (Maryunus, 2018).

The type of epiphytes attached to the seaweed thallus is *Neosiphonia sp.,* characterized by the presence of small black spots on the surface of the thallus, which indicate the occurrence of tetrasporeling embedded in the seaweed cortex layer (Vairappan *et al*., 2008). It is this process that begins the solitary growth of epiphytic plants which will leave a dark hole in cortical swelling. The highest level of epiphytic attachment in this study occurred in the middle of the dry season (July-Aug), where in that month the water temperature was 30-31.5^{o}C, salinity 33-35 ppt (Largo *et al*., 2017), flow velocity 4.5-6,8cm/sec (Sulistiawati *et al*. 2020) and nitrate concentrations of 0.1-0.25ppm (Mustafa *et al*., 2017), are less than optimal conditions for seaweed growth, so seaweed is brittle, slimy and easy a fracture that is likely to develop epiphyte infection.

Ice-Ice Disease

After epiphytic attachment occurs, another phenomenon that arises is the emergence of ice-ice infection in the seaweed thallus. This disease is a seasonal disease in seaweed, which is a disease that appears in certain seasons. During the study, it was noted that the presence of this disease was seen in the dry season in September-October. In contrast to weeds and epiphytes, ice-ice disease infection in seaweed is characterized by a change in the color of the talus to turn pale yellow and eventually turn white and break easily (Maryunus, 2018). The cause of ice-ice disease in seaweed is also caused by extreme conditions, such as increased temperatures and high sunlight intensity (Danilo B. Largo, 2020).

This ice-ice disease attacks both seaweed that is cultivated onshore and offshore. According to (Beveridge, 2008; Maryunus, 2018), the existence of ice-ice disease occurs when seaweed is under pressure due to drastic environmental changes. As a form of self-defense in the event of environmental changes, the seaweed will emit organic substances in the form of mucus. In addition, the things that cause ice-ice epiphytic infections include the occurrence of high temperature and salinity fluctuations, extreme seasonal changes, high levels of macroalgae density in the seaweed thallus and the lack of nutrients in the marine waters environment (Syamsuddin and Rahman, 2014; Rama *et al*., 2018), and the seaweed photosynthesis process was not optimal (Erbabley *et al*., 2018).

Conclusion

From this study, it can be concluded that there is relation between weed density, epiphyte attachment, and infection of ice-ice disease with seasons and locations. The peak of weed density in the seaweed cultivation area occurs at the beginning of the dry season, which is May-July which is dominated by *Sargassum sp.* (431.25g/m) and followed by *Ulva sp.* (137.5g/m) offshore. While epiphytic attachment and ice-ice infection occur at the end of the dry season from September to October.

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GROWTH RESPONSE OF *Kappaphycus alvarezii* OF GREEN STRAIN SEAWEED CULTIVATED ON DIFFERENT SEASONS AND LOCATIONS IN INDONESIA

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ABSTRACT

Seaweed is one of the Indonesian commodity exports, which is mostly obtained from the cultivation activities. The seaweed cultivation activity is commonly performed by the coastal community in coastal area using a longline method. There are several problems occured in the coastal area, such as land usage conflict, high pollutant, and sedimentation that affects the cultivated seaweed. Offshore area is an alternative location for seaweed cultivation to provide better water quality for supporting the seaweed growth. This study was aimed to compare the absolute and specific growth rate of seaweed cultivated at inshore and offshore locations, examine the optimum growth rate of seaweed, and determine the maximum growth rate of seaweed cultivated on different seasons. This study was conducted at Punaga Village for one year (2018) using a long line method. We cultivated the *Kappaphycus alvarezii* green strain at two different locations, i.e inshore and offshore location for one year round. We measured the parameters three times for each season comprising transitional seasons (Apr – May and Oct – Nov) and dry season (beginning (May – July), peak (July – August) and end (August - Oct)). Parameters measured were the absolute and specific growth rate, as well as the water quality (nitrate, phosphate, ammonium, CO_2, calcium and magnesium). The results showed that the growth rate of seaweed and concentration of nitrate, CO_2 and calcium were higher at the inshore location than at the offshore location. Meanwhile, the offshore location showed high phosphate and magnesium concentration.

Keywords: Inshore and offshore location; *Kappaphycus alvarezii* green strain; season; absolute and specific growth rate of seaweed.

INTRODUCTION

Seaweed is one of the potentially developed commodities as utilized widely on various sectors. Seaweed has been utilized in the food and feed industries [1], cosmetic industries [2], pharmacies [1] and energy [3]. Seaweed in the fisheries sector is utilized as a commercial feed ingredient [4,5].

The seaweed production in Indonesia is mostly obtained through the cultivation activities. The seaweed cultivation is mostly performed by the community live in high primary productivity [6]. The seaweed types cultivated in Indonesia, especially in the eastern region, are *Kappaphycus alvarezii* of green and brown strains.

The seaweed production which is cultivated in nature extremely depends on the natural condition, therefore the harvesting results are varied on each cultivation period at the different season. The growth of *Kappaphycus alvarezii* in Saugi Island was reported higher on the rainy season than dry season [7]. Meanwhile, the production of *Sargassum* spp. was high at the warm temperature and low on the rainy season in Australia (Fulton et al. 2014). The water supply mass difference causes the water condition alteration, which influences high and low water productivity.

Environmental parameters hold an important role in determining the seaweed production (Harrison and Hurd, 2001). Water physical factors, such as light, temperature [7] and nutrients are the essential factors for an algae as often altered dramatically along with an altered season (Kain, 2007). The rainy and dry seasons which occur in Indonesia have great different characteristics, specifically on the light factor.

Besides water physical and chemicals, location factor can also influence on the seaweed growth. The location of seaweed cultivation is an offshore and inshore using a longline method. Offshore is deeper water area with a strong current [8], while inshore is characterized by the nutrient rich location with mangrove and seagrass ecosystem, as well as coral reef ecosystem, which give a benefit for the seaweed development, especially the thallus growth, besides protected from small islands and corals, having a relatively stabile current, therefore unable to destruct the seaweed and cultivation facilities (Holmer, 2013). In this study, we will report the growth rate of *Kappaphycus alvarezii* (Doty) green strain on different seasons and cultivation locations.

MATERIALS AND METHODS

Description of the Study Sites

This study was conducted in Malelayya Village, Punaga Village, Mangarabombang Subdistrict, Takalar Regency, South Sulawesi. This study was performed in a year, which divided into five cultivation periods, namely the rainy to dry transitional season (April-May), beginning of dry season (May-June), mid dry season (July-August), end of dry season (September-October), and dry to rainy transitional season (October-November). All cultivation periods were performed for 45 days by calculating the absolute growth and specific growth rate (SGR). The seaweeds were cultivated at two different water locations, i.e water location near the shore (inshore) and water with steep slope in its base (offshore), using a longline method (Kasim and Mustafa, 2017). Seaweed growth and water quality data were collected during the study.

SGR is presented as the daily growth percentage based on the formula of Luhan and Sollesta (2010): $SGR = (\ln W_t/\ln W_0)/t x100\%$, as SGR is the specific growth rate (% wet weight per day), Wt is the weight after t day; Wo is the initial weight; t is time in days as obtained from each 15 days per cultivation period. Temperature, salinity, brightness, pH, and current speed was measured directly in the cultivation locations (*in* situ), while NO_3, NH_4, PO_4, CO_2, Mg, and Ca parameter were analyzed in the laboratory of water quality, Hasanuddin University, Makassar.

Statistical Analysis

Growth data were statistically analyzed using Mann-Whitney test with SPSS version 36.0, while the water quality was descriptively analyzed.

RESULTS

Kappaphycus alvarezii Green Strain Growth at the Inshore and Offshore Area

K. alvarezii green strain seaweed cultivated at the inshore and offshore area showed a different production. The growth rate of seaweed at the inshore showed higher value than offshore as the absolute growth of seaweed on the inshore and offshore area was 108.6 g: 5.44%, while the specific growth rate was 53.4 g: 3.9%.

Mann-Whitney test results showed the average growth of *K. alvarezii* green strain indicated a higher absolute growth and specific growth rate on the inshore area than offshore area (<0.05) (Fig. 1).

Kappaphycus alvarezii Green Strain Growth at the Inshore on Different Seasons

K. alvarezii green strain seaweed cultivated at the inshore area showed a different growth rate on dry and rainy season. The highest seaweed growth was obtained from the rainy to dry transitional season with 153; 142 g and at the dry to rainy transitional season with 6,11; 6,26%, as well as at the end of dry season before entering the dry to rainy transitional season with 97 g and 5,30% and the last was at the beginning and mid dry season with 77; 74 g and 4,77; 4,75% respectively. The Mann-Whitney test showed that the seaweed growth at the transitional seasons had no significant difference (>0,05). This was different from the seaweed growth at the dry season with the transitional season, showing a significant difference (<0,05), while the growth rate at the end of dry season had no significant difference (>0,05) (Fig. 2).

Kappaphycus alvarezii Green Strain Growth at the Offshore on Different Seasons

K. alvarezii green strain seawood cultivated at the offshore area on rainy and dry season showed that the seaweed strain green can be cultivated annually as same as the inshore area (Fig. 3). The highest growth rate of seaweed at the offshore was found on the dry to rainy transitional season with 95 g and 5.23% and rainy to dry transitional season with 56; 64 g and 4.47; 4.30%. The lowest value was obtained from the seaweeds cultivated on the dry season with 22; 30 g and 2.57; 3.06%. The Mann-Whitney test indicated that the seaweed cultivated on the transitional seasons from dry to rainy season had the highest growth rate (0<0.05) compared to other seasons. Meanwhile, the growth of seaweed on the rainy to dry transitional season showed higher value than at the end of dry season (0.05).

Water Quality

The water quality parameters that support the seaweed growth on each cultivation location are presented on Tables 1 and 2. The following results indicated that physical parameters, salinity, temperature, pH, or brightness had a relatively same value on either inshore or offshore area. Meanwhile, the chemical parameters, such as NH_4, NO_3, and PO_4, as well as chlorophylls presented a higher concentration at the inshore area than the offshore. Moreover, the content of CO_2, Ca, and Mg which played the roles in the photosynthesis process had a relatively same value.

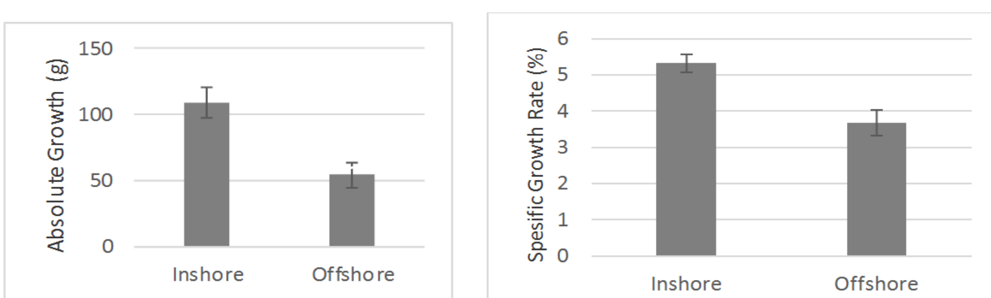

Fig. 1. Growth of *K. alvarezii* of green strain at inshore and offshore. Absolute growth (a); Specific growth rate (b)

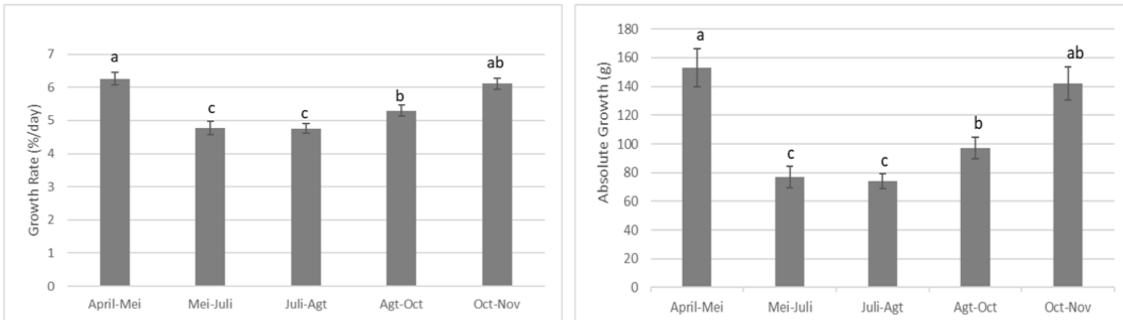

Fig. 2. Growth of *K. alvarezii* of green strain at inshore on different seasons. Absolute growth (a); Specific growth rate (b)

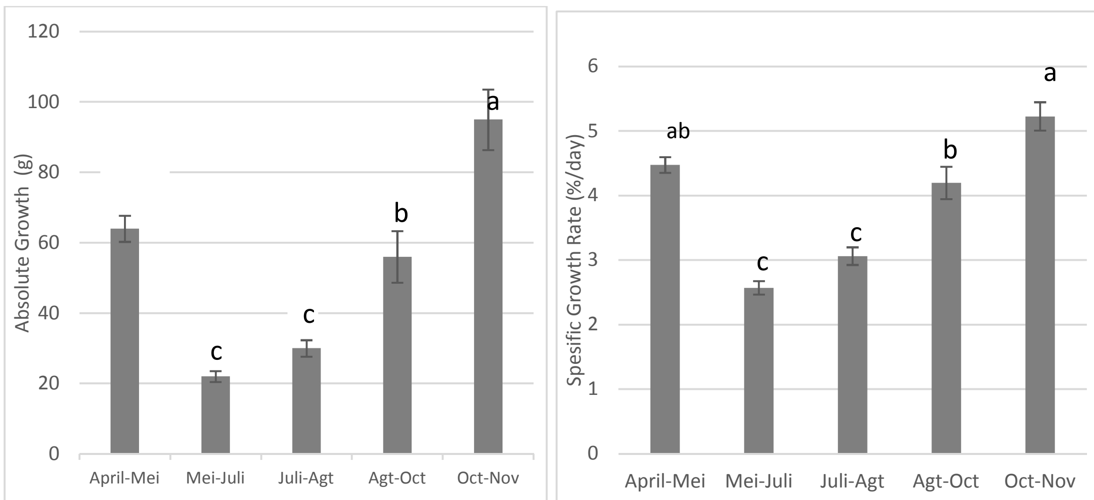

Fig. 3. Growth of *K. alvarezii* green strain at the offshore area on different seasons. Absolute growth (a); Specific growth rate (b)

Table 1. The water concentration of salinity, temperature, pH, and brightness on different locations and seasons

Parameter	Unit	Location	Season				
			I	II	III	IV	V
temperature	°C	inshore	28.5-30.5	30.0-31.0	30.0-31.5	30.0-31.0	29.0-30.5
		offshore	29.0-31.0	30.0-31.5	30.1-31.5	30.5-31.1	30.0-31.1
salinity	ppt	inshore	33.9-35.1	34.5-35.0	33.5-35.5	33.0-34.0	31.1-33.0
		offshore	33.5-35.5	35.0-35.5	33.9-35.0	33.0-34.5	31.5-33.0
Brightness	%	inshore	100	100	100	100	100
		offshore	100	100	100	100	100
pH	-	inshore	7.53-7.64	7.53-8.3	7.65-8.2	7.9-8.0	7.53-8.1
		offshore	7.83-7.97	7.89-7.97	7.89-8.1	7.5-7.9	7.53-7.9
Current speed	cm/s	inshore	5.8-6.5	4.5-6.5	4.5-5.5	4.0-5.5	5.5-6.46
		offshore	6.5-7.5	5.0-6.5	5.4-6.8	6.5-7.5	7.8-8.5

I = Rainy to dry transitional season (April-May)
II = Beginning of dry season (May-June)
III = Mid dry season (July-August)
IV = End of dry season (September-October)
V = Dry to rainy transitional season

Table 2. The supporting parameter concentration of growth and photosynthesis process on different locations and seasons

Parameter	Unit	Zone	Parameter				
			I	II	III	IV	V
NH_4	ppm	inshore	0.001-0.002	0.001-0.002	0.001-0.002	0.002-0.003	0.002-0.003
		offshore	0.001-0.002	0.001-0.002	0.001-0.002	0.002-0.003	0.002-0.003
PO_4	ppm	inshore	0.5-0.71	0.2-0.4	0.4-0.49	0.49-0.60	0.5-0.72
		offshore	0.6-0.72	0.2-0.4	0.4-0.69	0.69-0.72	0.71-0.78
NO_3	ppm	inshore	0.4-0.46	0.19-0.25	0.15-0.25	0.15-0.27	0.43-0.5
		offshore	0.2-0.58	0.1-0.2	0.1-0.2	0.15-0.2	0.35-0.41
CO_2	ppm	inshore	15.34-22.76	22.76-29.97	27.95-29.97	25-96-27.95	22.50-25.96
		offshore	23.95-28.45	21.97-28.45	21.97-31.96	31.95-31.96	28.45-31.95
Ca	ppm	inshore	920-1023	920-1041	1041-1282	1281-2403	1023-2403
		offshore	920-1024	920-1041	1041-1401	1401-2121	1024-2121
Mg	ppm	inshore	4861-4909	4861-5637	3020-5637	3020-3911	3911-4681
		offshore	4822-4884	4822-5504	2634-5504	2634-3707	3707-4822

I = Rainy to dry transitional season (April-May)
II = Beginning of dry season (May-June)
III = Mid dry season (July-August)
IV = End of dry season (September-October)
V = Dry to rainy transitional season

DISCUSSION

Based on the results, the highest growth was obtained from the inshore area on the rainy to dry transitional season, as well as dry to rainy season. The different seawed growth was caused by the existence of water quality characteristic differences as cultivation media. The nutrient content in water near the shore is higher than water far from the shore [9].

Nutrient requirements for the optimal seaweed growth is very important in the production system [10]. The same condition was also explained by [11], when the seaweed nutrient requirement is greater than the available nutrients in water, therefore the nutrients will become a limitting growth factor or the unfulfilled term of minimum nutrient requirement that will limit the seaweed growth rate. Besides minimum requirement, growth is also affected by the interaction of balanced nutrient required by the seaweed, i.e phosphate and nitrate [12].

The main nutrients required by the seaweed to improve growth and production system are NO_3, PO_4 and CO_2 [13]. The NO_3 content showed higher value at the inshore area. Nitrogen in the form of NO_3, NH_4, and phosphate are naturally the nutrients as whenever unavailable, they will limit the seaweed growth. These nutrients can be available with the help of seawater movement under the thermocline layer or upwelling [10]. Moreover, water movement can also clean the seaweed from dirts that can inhibit the photosynthesis process, therefore seaweed can perform the photosynthesis process well.

Water mass mixing at the inshore area happens thermally on the transitional season, then will form a thermal stratification when entering the dry season and water stirring happens on the next transitional season [14]. The existence of water mass circulation impacts on the nutrient distribution contained in the water. High nutrien contents during the transitional season was caused by the water stirring occured marked from high current speed. The same condition was also stated by [15] that temperature alteration happens during the transitional season, whereas the temperature surface would induce or reduce randomly or the temperature surface would reduce rather drastically, impacting the nutrient circulation perfectly.

CONCLUSION

Based on the study results and analysis described, it can be concluded that *K. alvarezii* can be cultivated annually either on the rainy or dry season. The best growth rate was seen on the seaweed cultivated on the transitional season, either rainy to dry or dry to rainy season. Meanwhile, a cultivated location selection between inshore and offshore presented a higher growth at the inshore than offshore. This difference can not be separated from the supplied nutrients and nature condition in the field.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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