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Growth rate and carrageenan yield of *Kappaphycus alvarezii* (Rhodophyta, Gigartinales) cultivated in Kolambugan, Lanao del Norte, Mindanao, Philippines

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Abstract. The growth and carrageenan content of *Kappaphycus alvarezii* (Doty) Doty ex Silva (brown strain) cultivated in four coastal barangays of Kolambugan, Lanao del Norte namely; Barangay Manga, Simbuco, Tabigue and Mukas were determined for a period of 12 months. Some environmental parameters were also obtained: water temperature, salinity, water flow and inorganic phosphate and nitrate. Results showed great variability in growth rate and carrageenan content with sampling periods and sites. Higher growth rate and carrageenan yield occurred during the southwest monsoon from June to September, and lower growth rate occurred during the northwest monsoon from October to May in all of the sampling sites. Multiple stepwise regression analysis showed that water temperature and salinity were the environmental factors that affect growth and carrageenan yield in all of the sampling sites. Maximum growth and carrageenan yield were obtained during the southwest monsoon (June - September) when water temperature and salinity was at the range of 28^0C – 31^0C and 24‰ - 30‰, respectively. Based on the present study, it can be seen that there is a potential for *K. alvarezii* cultivation in Kolambugan, Lanao del Norte since the growth and carrageenan yield were within the commercial requirement desirable for commercial crops. The seasonal variations in growth rate and carrageenan yield can be related to seawater temperature and salinity. Water flow and inorganic phosphate were the other factors that can influence carrageenan yield.

Key Words: Growth rate, carrageenan, *Kappaphycus alvarezii*, seaweed.

Introduction. Seaweeds have been used since ancient times as food, fodder, fertilizers and as source of medicine. They are used as raw material for many industrial productions like agar, algin and carrageenan (Mishra et al 1993). The great demand for carrageenans in the world market has encouraged the commercial production of carrageenophytes through mariculture (Trono & Lluisma 1992). In fact, seaweed mariculture is now recognized as a very productive alternative source of livelihood and employment especially in developing countries in tropical Asia where a large portion of the shallow coastal fishery resources have been or are depleted (DA-BFAR 1988).

The Philippines is one of the few countries in the world that has successfully grown seaweeds in substantial commercial quantities. It is the major source of carrageenophytes in the world market (James 1990). Similarly, it ranks number one in terms of amount of production among the marine-based products, and it is one of the top three export commodities, thus contributing a large source of revenue to the country (DA-BFAR 1999).

Seaweed cultivation in the Philippines began in 1969 to 1970 using material of *Kappaphycus alvarezii* and *Eucheuma denticulatum* known as “cottoni” and “spinosum”, respectively (Lim & Porse 1981). *K. alvarezii*, the most popular variety of Kappaphycus, is characterized by its long and cylindrical thallus and sparse branches with sharp pointed tips (Hurtado et al 2008). It is an important source of *kappa* carrageenan, a hydrocolloid that has been widely used in industry as gelling and thickening agent. This has been farmed successfully in the Philippines since the 1970s, and derived strains have been introduced in more than 20 countries for mariculture purposes (Trono 1993; Ask & Azanza 2002; Paula et al 2002). About 120,000 dry tonnes year^{-1} of *K. alvarezii* are harvested mainly from the Philippines, Indonesia and Tanzania (Zanzibar), and it is responsible for the 70% of worldwide processed raw seaweed for carrageenan production (Areces 1995; McHugh 2003).

The productivity of an established farm depends on the management efficiency (Santelices 1999). Information about the *K. alvarezii* growth and carrageenan yield in commercial farms and recognition of the effect of the environmental factors and season on those variables is fundamental for management activities (Ask & Azanza 2002; Hayashi et al 2007a; Reis et al 2007; Hurtado et al 2001). Some studies have shown seasonality in growth rate and carrageenan yield in *K. alvarezii.* For example, Hurtado et al (2001) demonstrated strong seasonal changes in growth rate and carrageenan yield of *K. alvarezii* cultured in Panagatan Cays, Caluya, Antique. Highest growth rate and yield was obtained during peak months (January - February) while the lowest growth rate and yield was obtained during lean months (July - August). In Camranh Bay, Vietnam, growth and carrageenan yield of *K. alvarezii* was higher from September to February and lower from March to August (Hung et al 2009).

Environmental factors also affect the growth and carrageenan content of *K. alvarezii.* Temperature, light intensity and nutrients were believed to be the most important factors affecting *Kappaphycus* growth (Glenn & Doty 1990). In Barangay Doña Consuelo, Ozamiz City, growth rate was strongly affected by nitrate while it was salinity that affected the carrageenan content of *K. alvarezii* (Adajar 2010; Benitez 2010). In Vietnam and Mexico, the growth rate of *K. alvarezii* was strongly affected by water temperature. On the other hand, growth rate and carrageenan content of *K. alvarezii* in southeastern Brazil was highly affected by water temperature and salinity (de Góes & Reis 2012).

Available literatures show then that growth and carrageenan profile of *K. alvarezii* especially in Mindanao areas are quite few.

The general objective of this study was to determine the growth rate and carrageenan content of *K. alvarezii* (Doty) Doty ex Silva (brown strain) cultivated in four coastal barangays of Kolambugan, Lanao del Norte namely; Barangay Manga, Simbuco, Tabigue and Mukas during the 12 month period. To achieve such general objective, the following were sought: (1) to determine the daily growth rate and carrageenan content of *K. alvarezii* in each of the sampling areas; (2) to determine some environmental parameters and (3) to determine how some environmental factors affect the growth and carrageenan content of *K. alvarezii*.

Material and Method. The study was conducted in the 4 farmed sites located in four coastal barangays of Kolambugan, Lanao del Norte: Barangay Manga (08° 0.09' North Latitude and 123° 0.82' East Longitude), Simbuco (08° 0.09 North Latitude and 123° 0.82 East Longitude), Tabigue (08° 0.10 North Latitude and 123° 0.83 East Longitude) and Mukas (08° 0.10 North Latitude and 123° 0.84 East Longitude), respectively (Figure 1). One farm site per coastal barangay was selected and treated as one sampling site. Each sampling site has been farmed with *K. alvarezii* (brown strain) using the hanging-monoline culture method at 8 m depth and were composed of sandy-muddy substratum.

Assessment of Daily Growth Rate of *K. alvarezii* was done once a month for a period of 12 months (April 2010 - March 2011). Six bunches of fresh samples of *K. alvarezii* thalli were taken randomly from one hanging-monoline per sampling site, placed in a labeled plastic bag, brought to the cottage and weighed immediately using a digital weighing balance.

The increase in weight of plants was measured after 45 days of culture. The average daily growth rates (DGR = % day^{-1}) were measured and expressed as the percent increase in wet weight per day according to the formula (Hung et al 2009):

$$DGR = [(W_t / W_o)^{1-t} - 1] \times 100$$

Where: W_0 = initial wet weight, W_t = weight after *t* days, t = time intervals (days).

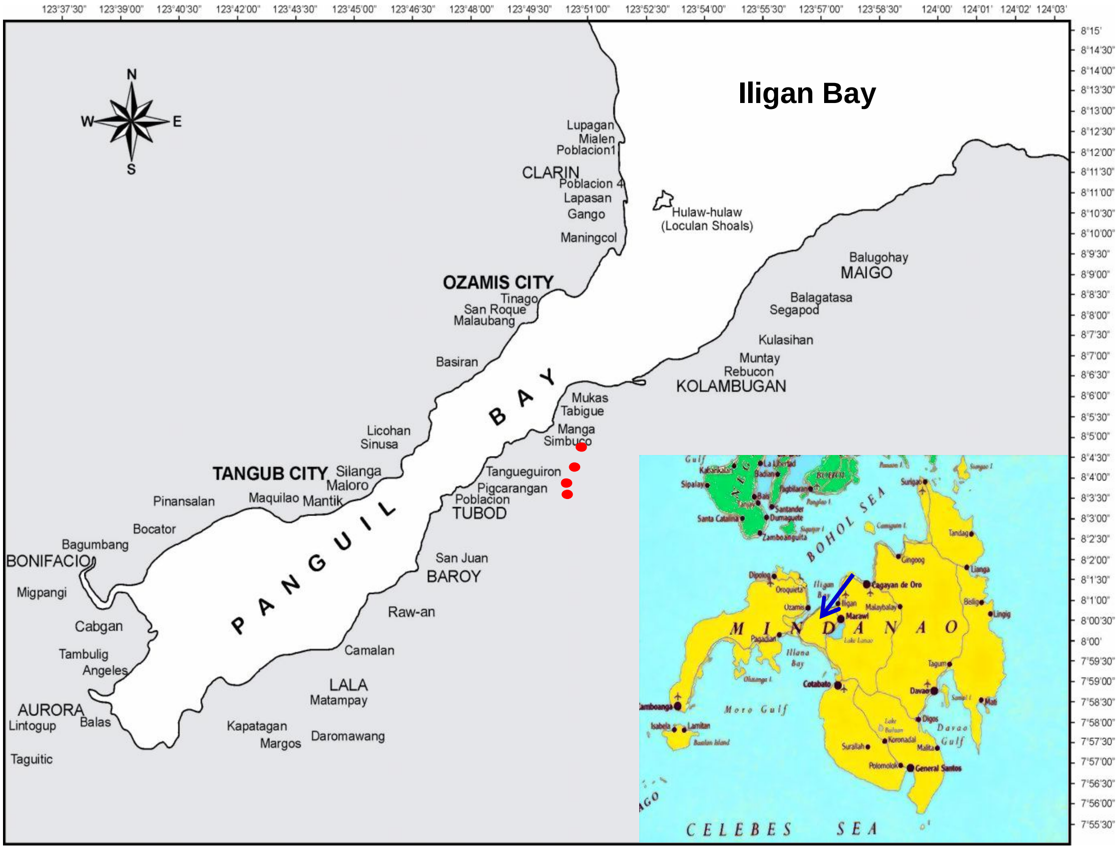

Figure 1. Map of Panguil Bay Northwestern Mindanao, showing the sampling area. Inset is the map of Mindanao with arrow pointing to Kolambugan, Lanao del Norte.

Fresh samples of *K. alvarezii* (brown strain) were collected once a month for a period of 12 months from each of the sampling sites. Five bunches of fresh samples of *K. alvarezii* thalli were taken randomly from one hanging-monoline per sampling site, placed in ice bucket and were transported to the laboratory where they were sorted, cleaned with water and were air dried for 1 day or more. The samples were blended and were air dried again for 2 days. The dried samples were ground into powder and were placed in a container prior to carrageenan extraction.

Carrageenan extraction was done following the method of Mtolera & Buriyo (2004) and Hayashi et al (2007b). About 3 g of powdered seaweeds was hydrated in 105 mL distilled water for 12 h at room temperature under agitation (to remove internal salts). The hydrated material was boiled using 105 mL distilled water at 60^0C for 4 h with constant stirring (to dissolve algal particles and evaporate insoluble materials). The digested product was precipitated in three volumes of 95% ethanol (210 mL). The precipitate was then filtered through a nylon cloth, dried in an oven at 60^0C for 24 h and at 105^0C for 2 h to constant weight, and then weighed. The final carrageenan was ground into powder for storage. The carrageenan yield (% dry weight) was determined according to the formula of Hung et al (2009):

$$\text{Yield} = (W_c / W_m) \times 100$$

Where: W_c = dry carrageenan weight, W_m = dry algal weight.

Environmental factors were measured at the depth (8 m) at which the cultured seaweed plants were growing. Measurement of environmental parameters was done once a month for a period of 12 months. Water temperature was measured using an ordinary mercury thermometer while salinity was measured using a handheld refractometer (Atago, Japan). Water flow was estimated using clod cards deployed at each of the sampling sites. Clod cards were prepared according to the general instructions of Doty (1971). Calculation of water flow (cm^{-2}) was done following the method of Anzai (2001). Nutrient analysis was carried out following the method of (Grasshoff et al 1983). Data are presented as means ±SD of at least five independent measurements. Statistical analyses were determined by Univariate Analysis of Variance. Pearson's correlation analysis was used to determine the correlation coefficients between environmental factors with growth rates and carrageenan content. Stepwise multiple regression was used to determine the individual contribution of environmental factors (independent variables) to the total variance of growth rate and carrageenan content (dependent variables), considering $P<0.05$. All statistical analyses were done using the SPSS software version 17.0.

Results and Discussion. The monthly variations in daily growth rate of *K. alvarezii* measured in the four sampling sites (Barangay Manga, Simbuco, Tabigue and Mukas) are presented in Figure 2. Significant differences in daily growth rates were observed among sampling sites and sampling periods ($P<0.05$; Table 1).

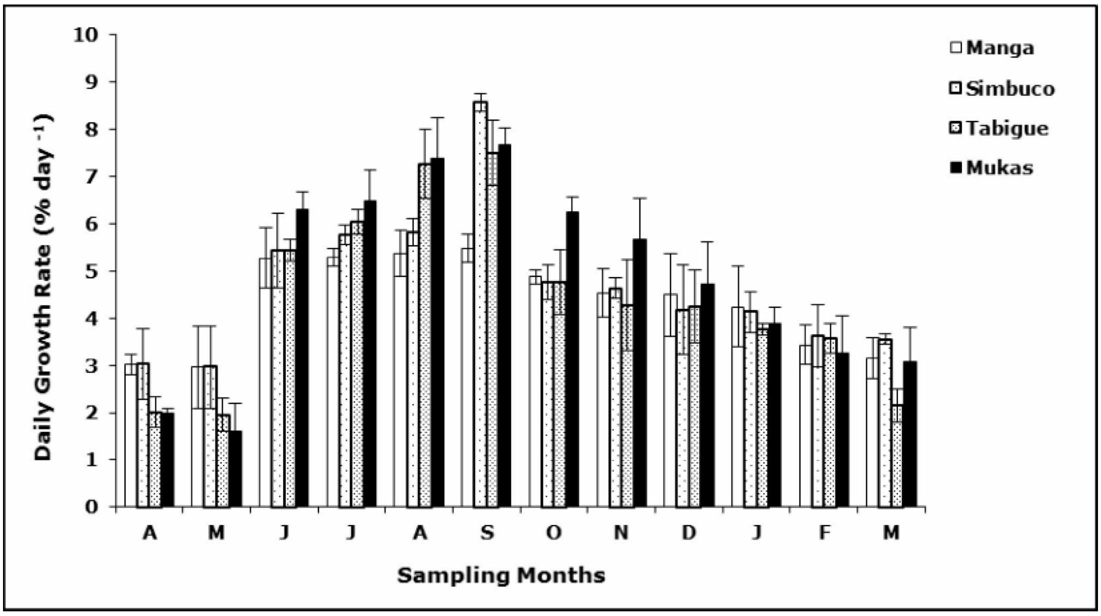

Figure 2. Monthly variation in daily growth rate of *Kappaphycus alvarezii* in Barangay Manga, Simbuco, Tabigue and Mukas, Kolambugan, Lanao del Norte (mean ± SD).

Table 1

Statistical analysis (Two-Way ANOVA) of the daily growth rate of *Kappaphycus alvarezii* among sampling sites and sampling periods

Source	*d.f.*	*F-statistics*	*p*	*Analysis*
Site	11	4.99	<0.05	Significant
Period	3	77.68	<0.05	Significant

The daily growth rates were higher from June to September while it was lower in October to May in all of the sampling sites. The high growth rate of *K. alvarezii* coincided with the southwest monsoon or "habagat" (June to September) which is characterized by strong wave action, lower temperatures and low salinity brought by monsoon rains. This result is in contrast with the study of Hurtado et al (2001) and Hung et al (2009) in which growth rate of *K. alvarezii* was minimal during the southwest monsoon. On the other hand, minimal growth rates occurred during the northeast monsoon or "amihan" which is characterized by low water motion and high water temperature. Also, the occurrence of "ice-ice" disease was observed during the months of April - May.

Over a 12 month period, the average growth rate of *K. alvarezii* obtained from the four sampling sites (Manga 2.97-5.49% day $^{-1}$; Simbuco 2.97-8.58% day $^{-1}$; Tabigue 1.96-7.51% day $^{-1}$; Mukas 1.61-7.68% day $^{-1}$) was comparable to rates reported for *Eucheuma cottonii* (*K. alvarezii*) [2.5-3.5% day $^{-1}$ (Adnan & Porse 1987)], 3.5-3.7% day $^{-1}$ (Luxton et al 1987), 2.5-3.5% day^{-1} (Mollion & Braud 1993), 0.1-8.4% day^{-1} (Dawes et al 1994), 0.13-8.12% day^{-1} (Ohno et al 1994), 1.1-3.4% day^{-1} (Hurtado-Ponce 1995), 4.0-11.0% day^{-1} (Ohno et al 1996), 0.2-4.2% day^{-1} (Hurtado et al 2001), 3.6-8.9% day^{-1} (Paula & Pereira 2003), 2.0-7.1% day^{-1} (Muñoz et al 2004), 3.1% day^{-1} (Hung et al 2009) and 1.1-5.3% day $^{-1}$ (de Góes and Reis 2012), indicating its commercial potential as reported by Doty (1987).

The monthly variations in carrageenan yield of *Kappaphycus alvarezii* are depicted in Figure 3. A significant difference in yield was seen among sampling sites and sampling periods ($P<0.05$, Table 2).

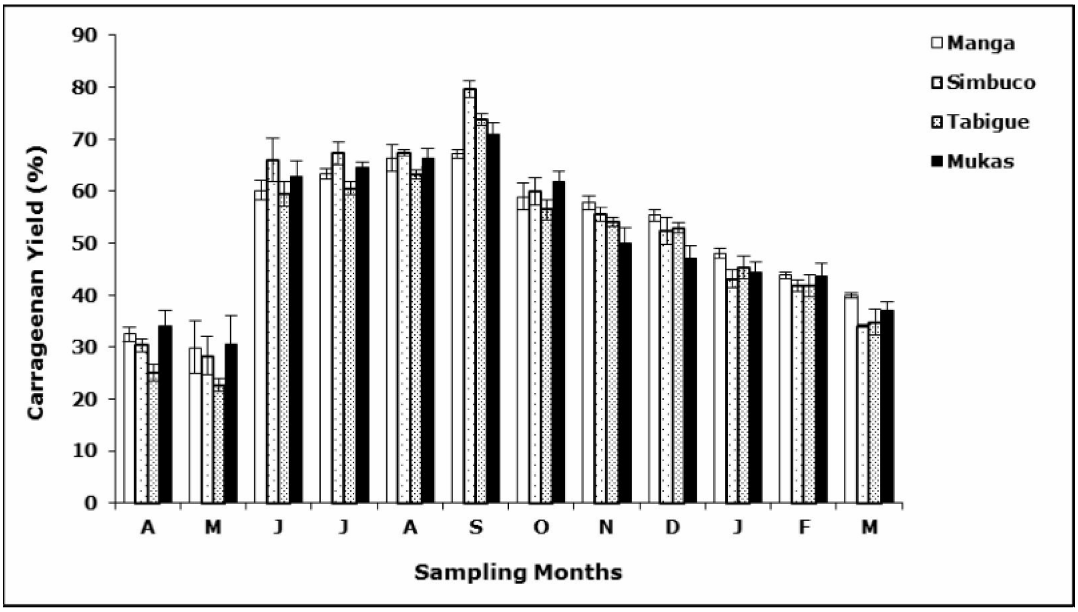

Figure 3. Monthly variation in carrageenan yield of *Kappaphycus alvarezii* in Barangay Manga, Simbuco, Tabigue and Mukas, Kolambugan, Lanao del Norte (mean ± SD).

Table 2
Statistical analysis (Two-Way ANOVA) of the carrageenan yield of *Kappaphycus alvarezii* among sampling sites and sampling periods

Source	*d.f.*	*F-statistics*	*p*	*Analysis*
Site	11	26.02	<0.05	Significant
Period	3	853.08	<0.05	Significant

In all of the sampling sites, the carrageenan yield was higher from June to September while it was lower in October to May. Similar with the result of the growth rate, the carrageenan yield was higher during the southwest monsoon or "habagat" and lower during the northeast monsoon or "amihan". The average carrageenan yield of *K. alvarezii* obtained from the four sampling sites (Manga 29.93-67.20%; Simbuco 28.33-79.62%; Tabigue 22.62-73.85%; Mukas 30.59-70.97%) was within the range of the industrial requirements for this species [~38% (Muñoz et al 2004)]. Also, the yield was higher compared to the values reported in Indonesia [45% (Trono & Ohno 1989)], China [56.9-58.0% (Li et al 1990)], Japan [27.6-43.5% (Ohno et al 1994)], Mexico [30.3-40.7% (Muñoz et al 2004)], Brazil [31-43% (Hayashi et al 2007a)] and Vietnam [40.9-46.8% (Hung et al 2009)]. These differences could be attributed to the extraction methodology used in the study, the morphotype of the species and/or the extracted raw material

(Ohno et al 1994, 1996; Hurtado-Ponce 1995). In addition, the higher carrageenan content obtained in the present study when compared to the other studies may be attributed to the growing conditions in the area.

The mean monthly values of the environmental parameters varied significantly among sampling sites and sampling periods ($P<0.05$, Figure 4, Table 3).

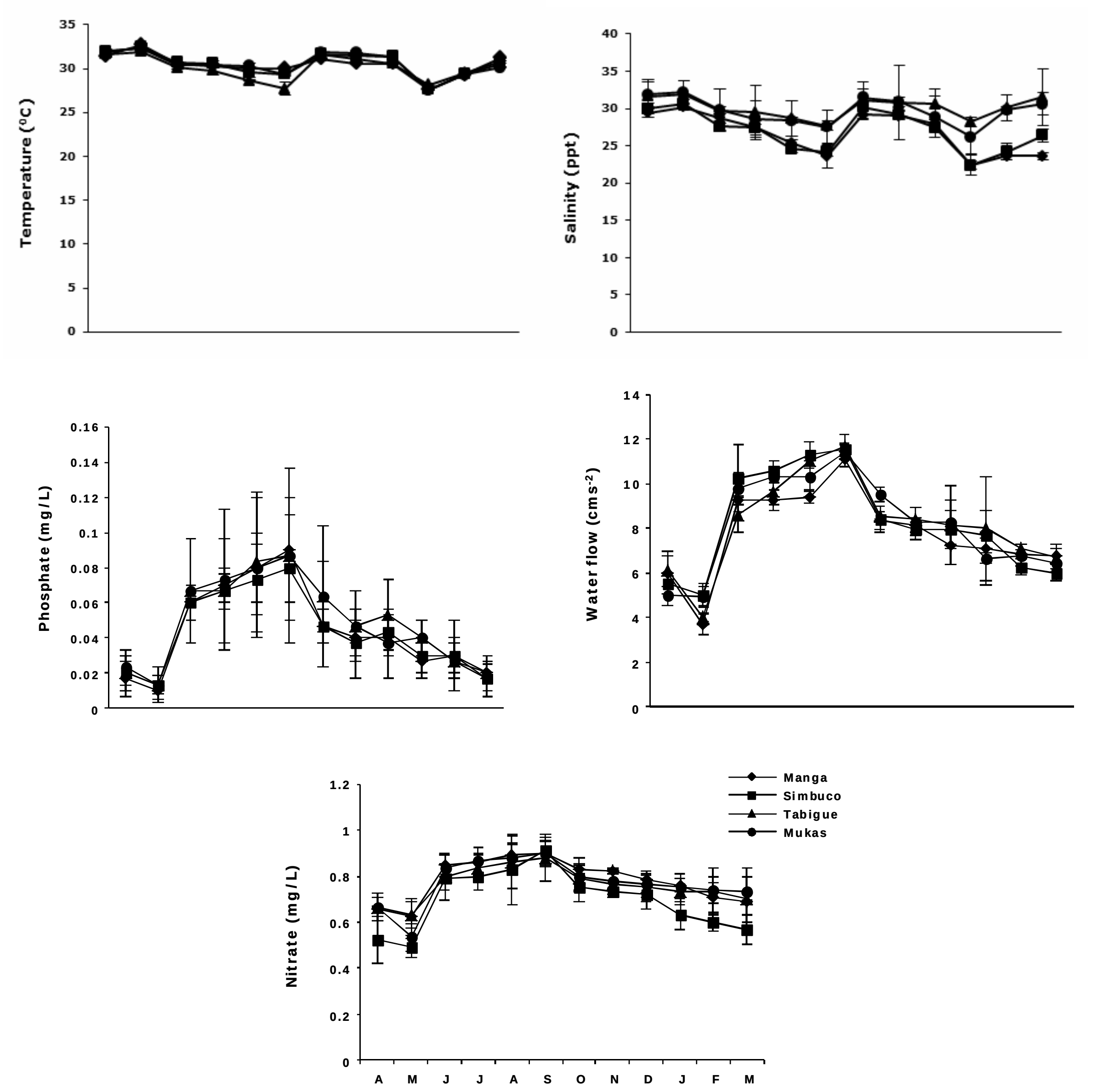

Figure 4. Monthly variation in environmental parameters measured in Barangay Manga, Simbuco, Tabigue and Mukas, Kolambugan, Lanao del Norte (mean ± SD).

The highest water temperature occurred from April to May while the lowest temperature occurred in January in all of the sampling sites. The water temperature in Barangay Manga range from 27.64–32.76^{0}C, 27.62-32.44^{0}C in Simbuco, 28.20–31.90^{0}C in Tabigue and 27.56–32.26^{0}C in Mukas, and were within the required levels for eucheumoid farming (Hurtado et al 2008). It was observed that the highest water temperature occurred during the dry or summer season (April - May). During this time growth and carrageenan content of *K. alvarezii* was very minimal coupled with the occurrence of "ice-ice" disease (personal observation).

Table 3

Statistical analysis (Two-way ANOVA) of the environmental parameters among sampling periods and sites (mean ± SD)

Parameters	Site				Period			
	n	*d.f.*	*F*	*p*	*n*	*d.f.*	*F*	*p*
Water temperature	5	3	6.825	<0.05	5	11	82.838	<0.05
Salinity	5	3	65.945	<0.05	5	11	28.541	<0.05
Water flow	3	3	2.896	<0.05	3	11	95.872	<0.05
Phosphate	3	3	220.124	<0.05	3	11	219.186	<0.05
Nitrate	3	3	10.870	<0.05	3	11	22.069	<0.05

The salinity pattern seemed to follow that of temperature – with higher values in dry or summer season than during the rainy season. Highest value was recorded from April to May while the lowest value was recorded during the month of January. In Barangay Manga, salinity range from 22.40–30.20 ‰, 22.40–30.60 ‰ in Simbuco, 27.67–31.90 ‰ in Tabigue and 26.20–32.20 ‰ in Mukas, and were within the required levels for eucheumoid farming (Hurtado et al 2008).

The water flow was highest from June to September while it was lowest from October to May in all of the sampling sites. The values recorded in Barangay Manga range from 3.71-11.12 cms^{-2}, 5.03-11.59 cms^{-2} in Simbuco, 3.99-11.72 cms^{-2} in Tabigue and 4.96-11.44 cms^{-2} in Mukas, respectively. The highest water flow occurred during the southwest monsoon (habagat) while the lowest water flow occurred during the northeast monsoon (amihan).

Similar trend in both inorganic phosphate and nitrate was observed in all of the sampling sites. The highest values recorded were from June to September while the lowest values were from October to May. The values of phosphate range from 0.01-0.09 mg/L in Barangay Manga, 0.01-0.08 mg/L in Simbuco, 0.01-0.09 mg/L in Tabigue and 0.01-0.09 mg/L in Mukas. On the other hand, the nitrate values in Barangay Manga range from 0.62-0.90 mg/L, 0.49-0.91 mg/L in Simbuco, 0.63-0.88 mg/L in Tabigue and 0.53-0.90 mg/L in Mukas, respectively.

Correlation coefficients among the environmental parameters analyzed for *K. alvarezii* in Barangay Manga, Simbuco, Tabigue and Mukas are shown in Table 4 to 7. The growth rate of *K. alvarezii* showed a significant positive correlation with carrageenan yield in all of the sampling sites. This result indicates that the maximum carrageenan yield corresponds to the highest growth rate and vice versa. Also, higher growth rate and carrageenan yield occurred during the southwest monsoon (June - September). This seasonal growth patterns and carrageenan yield of *K. alvarezii* has been observed elsewhere and in Kolambugan (Hung et al 2009; Muñoz et al 2004; Hurtado et al 2001; Ohno et al 1996; Prakash 1990).

Table 4

Correlation coefficients (R) between growth rate (% day^{-1}) and carrageenan yield (%) of *Kappaphycus alvarezii* with environmental parameters in Barangay Manga, Kolambugan, Lanao del Norte. Daily growth rate (DGR), Carrageenan yield (CY), Temperature (Temp), Salinity (Sal)

Specification	*DGR*	*CY*	*Temp*	*Sal*	*Water flow*	*Phosphate*	*Nitrate*
DGR	1	-	-	-	-	-	-
CY	0.648**	1	-	-	-	-	-
Temperature	-0.421**	-0.314*	1	-	-	-	-
Salinity	-0.493**	-0.343**	0.818**	1	-	-	-
Water flow	0.495**	0.025	-0.160	-0.444**	1	-	-
Phosphate	0.367*	0.234	-0.100	-0.360*	0.741**	1	-
Nitrate	0.459**	0.059	-0.114	-0.354*	0.723**	0.720**	1

*represents significant differences at $p<0.05$, **represents significant differences at $p<0.01$.

Table 5

Correlation coefficients (R) between growth rate (% day^{-1}) and carrageenan yield (%) of *Kappaphycus alvarezii* with environmental parameters in Barangay Simbuco, Kolambugan, Lanao del Norte. Daily growth rate (DGR), Carrageenan yield (CY), Temperature (Temp), Salinity (Sal)

Specification	*DGR*	*CY*	*Temp*	*Sal*	*Water flow*	*Phosphate*	*Nitrate*
DGR	1	-	-	-	-	-	-
CY	0.782**	1	-	-	-	-	-
Temperature	-0.389**	-0.281*	1	-	-	-	-
Salinity	-0.508**	-0.438**	0.905**	1	-	-	-
Water flow	0.397*	0.052	-0.292	-0.267	1	-	-
Phosphate	0.346*	0.042	-0.338*	-0.349*	0.655**	1	-
Nitrate	0.239	0.095	-0.059	-0.045	0.787**	0.506**	1

*represents significant differences at $p<0.05$, **represents significant differences at $p<0.01$.

Table 6

Correlation coefficients (R) between growth rate (% day^{-1}) and carrageenan yield (%) of *Kappaphycus alvarezii* with environmental parameters in Barangay Tabigue, Kolambugan, Lanao del Norte. Daily growth rate (DGR), Carrageenan yield (CY), Temperature (Temp), Salinity (Sal)

Specification	*DGR*	*CY*	*Temp*	*Sal*	*Water flow*	*Phosphate*	*Nitrate*
DGR	1	-	-	-	-	-	-
CY	0.803**	1	-	-	-	-	-
Temperature	-0.506**	-0.594**	1	-	-	-	-
Salinity	-0.289*	-0.248	0.213	1	-	-	-
Water flow	0.054	0.359*	-0.112	-0.053	1	-	-
Phosphate	0.105	0.396*	-0.262	-0.185	0.630**	1	-
Nitrate	0.103	0.242	-0.024	-0.197	0.688**	0.508**	1

*represents significant differences at $p<0.05$, **represents significant differences at $p<0.01$

Table 7

Correlation coefficients (R) between growth rate (% day^{-1}) and carrageenan yield (%) of *Kappaphycus alvarezii* with environmental parameters in Barangay Mukas, Kolambugan, Lanao del Norte. Daily growth rate (DGR), Carrageenan yield (CY), Temperature (Temp), Salinity (Sal)

Specification	*DGR*	*CY*	*Temp*	*Sal*	*Water flow*	*Phosphate*	*Nitrate*
DGR	1	-	-	-	-	-	-
CY	0.902**	1	-	-	-	-	-
Temperature	-0.160	-0.215	1	-	-	-	-
Salinity	-0.603**	-0.668**	0.388**	1	-	-	-
Water flow	0.108	0.069	-0.724**	-0.287	1	-	-
Phosphate	0.120	0.138	-0.228	-0.184	0.230	1	-
Nitrate	0.146	0.012	-0.492**	-0.062	0.765**	0.108	1

*represents significant differences at $p<0.05$, **represents significant differences at $p<0.01$.

The growth rate in Barangay Manga was negatively correlated with water temperature and salinity, and positively correlated with water flow, phosphate and nitrate showing that the period of minimal growth corresponds to the highest water temperatures and salinity, and lowest water flow and amount of inorganic phosphate and nitrate while the carrageenan yield showed a negative correlation with temperature and salinity.

Similarly, in Barangay Simbuco, growth was negatively correlated with water temperature and salinity, and positively correlated with water flow and phosphate while the carrageenan yield was negatively correlated with water temperature and salinity.

The growth rate in Barangay Tabigue was negatively correlated with water temperature and salinity. On the other hand, the carrageenan yield was negatively correlated with water temperature and salinity, and positively correlated with water flow and phosphate.

In Barangay Mukas, growth and carrageenan yield was both negatively correlated with salinity.

Multiple stepwise regression analysis identified salinity as the environmental factor that explained 46% and 18% of the observed variation in *K. alvarezii* growth rate (R^2 = 0.46 and 0.18) and carrageenan content in Barangay Manga, respectively. On the other hand, inorganic phosphate explained 35% of the variation in carrageenan yield in Barangay Manga. Temperature was the only environmental factor that explained 29% and 14% of the observed variation in growth rate and carrageenan yield in Barangay Simbuco, respectively. In Barangay Tabigue, temperature explained 21% and 27% variation in growth rate and carrageenan content, respectively while water flow explained 36% variation in carrageenan content. Lastly, in Barangay Mukas, salinity explained 44% and 16% variation in growth rate and carrageenan, respectively.

In the present study, temperature and salinity were the main environmental factors affecting the growth rates of *K. alvarezii* in most of the sampling sites. Maximum growth rates were obtained during the southwest monsoon from June to September. The average seawater temperature readings were 27.67-30.72^{0}C and salinity readings were 23.60–29.80 ‰. It appears that temperatures in the range of 28^{0}C–31^{0}C and salinity in the range of 24-30 ‰ are favorable to allowing *K. alvarezii* to obtain high growth rate. A negative correlation between temperature and growth rate of *K. alvarezii* has also been reported (Glenn & Doty 1992; Muñoz et al 2004), and likewise with salinity (Hung et al 2009), seemingly consistent with the negative correlation between temperature and salinity in this study.

The changes in carrageenan yield were also dependent on different environmental factors. Water temperature, salinity, inorganic phosphate and water flow were the main environmental factors affecting carrageenan content. Similar to growth rate, carrageenan yield was highest from June to September that coincides with the southwest monsoon. Maximum carrageenan yield was obtained when water temperature and salinity was at the range of 28^{0}C–31^{0}C and 24-30 ‰, respectively. On the other hand, the period of maximal carrageenan yield corresponds to the highest amount of inorganic phosphate and water flow. The strong water movement during the southwest monsoon increases hydrodynamics and consequently increases growth and carrageenan yield in all of the sampling sites. Moreover, Fuller & Mathieson (1972) stated that other factors that would produce seasonal changes in carrageenan content are nutrient availability. Recently, phosphorus has been recognized as a nutrient that, together with nitrogen, has an important role in algal growth and carrageenan content (Lapointe 1987; Chopin et al 1990). In this study, a significant positive correlation in phosphate and carrageenan content was observed especially in Barangay Manga, Simbuco and Tabigue. The maximum carrageenan yield was obtained during the period of highest nutrient supply. A similar positive interaction has been observed in *Eucheuma isiforme* from Yucatán, Mexico (Freile-Pelegrin & Robledo 2006).

Conclusions. Based on the present study, it can be seen that there is a potential for *K. alvarezii* cultivation in Kolambugan, Lanao del Norte since the growth and carrageenan yield were within the commercial requirement desirable for commercial crops. The seasonal variations in growth rate and carrageenan yield can be related to seawater temperature and salinity. Water flow and inorganic phosphate were other factors that can influence carrageenan yield. The maximum growth and carrageenan yield occurred during southwest monsoon (June - September), coinciding with low water temperatures, low salinity, strong water movement and high nutrient concentrations. These results should be taken into consideration for the management of *K. alvarezii* either in natural populations or in commercial cultivation in the coastal areas of Kolambugan, Lanao del Norte.

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