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Growth and Health Status of *Kappaphycus alvarezii* Under Caged and Uncaged Conditions in Silaqui Island, Bolinao, Pangasinan, Northern Philippines

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Abstract - The study was conducted to compare the growth and health status of *Kappaphycus alvarezii* cultured under caged and uncaged conditions in Silaqui Island, Bolinao, Pangasinan from 21 November 2014 to 16 January 2015. Two bamboo rafts (2 m X 4 m) were used to support the mono-lines holding the seaweeds. One raft was enclosed with a net while the other raft had no net enclosure. A total of 32 *K. alvarezii* (100 g) propagules were tied in the mono-lines in the two rafts. The growth increment and occurrence of diseases and other health problems of *K. alvarezii* were determined weekly. Fish visual census was done weekly to determine the presence of fish grazers. Water quality parameters (i.e., temperature, salinity, light intensity and water movement) were also monitored. Results showed that the growth of *K. alvarezii* under open water condition was relatively higher than in the caged condition. However, the t-test failed to show significant difference between the two treatments. Based from experiences in the study, *K. alvarezii* cultured under uncaged, open water condition, can be dislodged by strong wind and water movement. In the caged condition, dislodged propagules were recovered at the bottom of the net and replanted again, suggesting that caged raft could be used in commercial cultivation of *K. alvarezii* because it could maximize the production by preventing the stocks from being lost as compared to an uncaged raft. Five diseases and health problems occurred during the study, namely, epiphytism, ice-ice disease, pitting, tip darkening, and tip discoloration. In the present study, fish grazing was not observed to occur under the open water condition during the eight-week study period.

Key words: Fish Grazing; *Kappaphycus alvarezii*; Growth; Health Status

INTRODUCTION

Kappaphycus alvarezii is an economically important red tropical seaweed with high demand as a source of kappa-carrageenan [1]. This species contributed about 80% of the total Philippine seaweed exports [2], thus making our country as the world's fourth largest producer of seaweeds in 2018 [3]. One of the common methods used in the culture of this seaweed is the floating raft method [2]. This method is advantageous because it minimizes grazing by benthic animals and the cultured seaweeds are exposed to some degree of water movement. It was even suggested to culture *K. alvarezii* in cages together with a carnivorous fish [4]. However, it also has disadvantages such as fish grazing by rabbit fishes and the loss of stocks during adverse weather conditions resulting to losses in production. In this study, the growth and health status of *K. alvarezii* under caged and uncaged conditions were compared to identify the better culture method to be used in Silaqui Island, Bolinao, Pangasinan.

MATERIALS AND METHODS

Research Design

The study used the experimental method to compare the growth of *Kappaphycus alvarezii* under caged and uncaged open water conditions in terms of absolute growth (weight gain), absolute growth rate (weight gain/d), relative growth (% weight gain) and relative growth rate (% weight gain/d). On the other hand, the descriptive method was used to determine the occurrence of diseases and other health problems of the seaweed based on observable gross signs and the identification of the possible fish grazers during the study.

Experimental Site

The study was conducted at the experimental seaweed farm (16°26’ 21.5” N, 119°54” 56.6” E) of the Bolinao Marine Laboratory (BML), University of the Philippines – Marine Science Institute (UP-MSI) located near Silaqui Island, Bolinao, Pangasinan (Figure 1) from 21 November 2014 to 16 January 2015. The substrate was generally sandy with patches of seagrass. Water depth ranged from 1.3 m during low tide to 2 m during high tide. The site was about 20-30 minutes boat ride from the Outdoor Hatchery of BML.

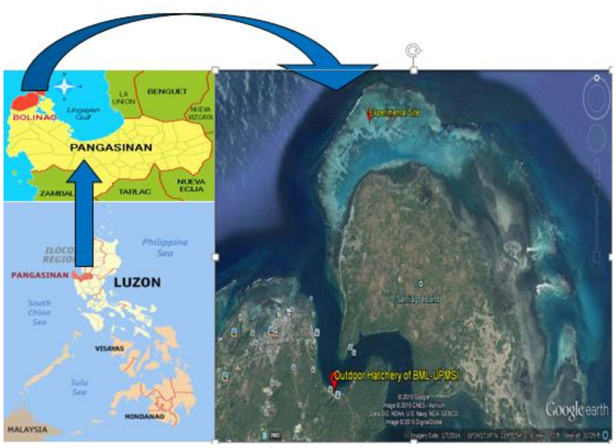

Figure 1. Location map of the study site.

Figure 2. Experimental treatments of the study: Caged Raft (Left) and Uncaged Raft (Right).

Experimental Treatments

Two treatments, caged and uncaged raft conditions, were used in the study. Two bamboo rafts measuring 2 m X 4 m were constructed and each raft supported 4 mono-lines (4 m long) made of polyethylene (PE, 8 mm size) and 50 cm apart from each other. One raft was enclosed with a net (2 m X 4 m X 0.12 m) made from a V-net (1 cm mesh) whereas the other raft had no enclosure (Figure 2). The rafts set 1.5 m away from each other were set in place by ropes tied to cement blocks laid on the bottom substrate.

A total of 16 *K. alvarezii* propagules (100 g) were tied in the mono-lines in each raft at 4 propagules per line with an interval of 50 cm. The arrangement of the propagules was rotated weekly to account for possible variations in environmental conditions as well as grazing.

Growth Monitoring

The weight of *K. alvarezii* was determined weekly using a 2000-g capacity analog weighing scale. The propagules were removed from the two rafts by cutting the plastic straws. The seaweeds were drained using an improvised plastic screen for 3-5 min to remove excess water before weighing. After weighing, the propagules were tied again to the mono-lines but the position of the mono-lines were rotated. The absolute growth, absolute growth rate, relative growth, and relative growth rates were determined using the following standard formulas [5].

Absolute Growth (Weight Gain) = wf – wi

Absolute Growth Rate (Weight gain/d) = (wf – wi)/no. of days

Relative Growth (% Weight Gain) = (wf – wi)/wi X 100

Relative Growth Rate = (wf – wi)/(wi)(no. of days) X 100

Determination of Diseases and Other Health Problems

On-site observations on the occurrence of diseases and other health problems were done weekly during sampling. The *K. alvarezii* was placed in a white plastic bin filled with seawater. The thalli were thoroughly inspected and the gross signs of diseases were noted. The diseases and other health problems were identified based on the Bureau of Fisheries and Aquatic Resources (BFAR) poster, entitled "Health Status of Seaweeds in the Philippines."

Identification of Fish Grazers

A fish visual census in the site was done weekly between 10:00 to 11:00 am to determine the presence of fish grazers in the site. The census was done for 15 minutes by snorkeling with slow movement so as not to disturb the fishes. Fish were photographed and identified using fish identification guides and through fishbase (www.fishbase.org) website.

Monitoring of Water Quality Parameters

Water temperature, salinity, light intensity, and water movement were monitored once during the study. Water temperature was monitored for 48 h during January 13-15, 2015 by deploying a HOBO Pendant Temperature data logger sensor. Salinity was monitored on 18 December 2014 using a refractometer. Light intensity was measured on 18 December 2014 using a LI-COR spherical sensor attached to a LI-1400 data logger at the depth where *K. alvarezii* were planted. The average of ten consecutive readings were determined. Water movement was estimated by deploying pre-weighed clod cards in each raft from 13-15 January 2015. Three clod cards were used in each raft and tied in the mono-line where seaweeds were located. Three other clod cards served as controls and placed in a large basin with seawater. After 48 h, all clod cards were retrieved, oven-dried for 24 h at 60°C, and weighed using an analytical balance. The diffusion indices were then computed to estimate the water movement using the formula below [6].

Diffusion Index = weight loss (g) in experimental set-up/weight loss (g) under controlled environment

Data Analysis

For growth comparison, the t-test was used to determine the statistical differences (5% level of significance) using Microsoft Excel. On the other hand, descriptive statistics were used to evaluate the health status of *K. alvarezii* and to identify and quantify the number of fish grazers.

RESULTS AND DISCUSSION

Growth of *K. alvarezii*

Table 1 presents the growth of *K. alvarezii* in the two treatments in terms of absolute growth, absolute growth rate, relative growth, and relative growth rate after 56 d of culture. Growth of *K. alvarezii* was faster under the open water condition. It had increased in weight by 1,735.56 g (1735%) and 1,593.13 g (1593.13%) under the uncaged and caged conditions, respectively after 56 d. A daily mean of 28.45 g (28.45%) and 30.99 g (30.99%) were added to its weight in the caged and uncaged conditions, respectively. However, the t-test failed to show significant differences in the above growth parameters in the two treatments ($P>0.05$). This suggests that the caged condition did not adversely affect the growth of *K. alvarezii*.

Table 1. Growth of *Kappaphycus alvarezii* under caged and uncaged conditions.

Treatment	Absolute Growth (g)	Absolute Growth Rate ($g.d^{-1}$)	Relative Growth (%)	Relative Growth Rate ($\%.d^{-1}$)
T1 (Caged)	1,593.13	28.45	1,593.13	28.45
T2 (Uncaged)	1,735.56	30.99	1,735.56	30.99

It was reported that a daily growth rate of 3.5%/d is considered significant in commercial cultivation of *Kappaphycus* sp. [7]. Using the same formula (DGR= ln (w_f/w_i)/t X 100), the corresponding DGR in the present study was 5.05% and 5.20%/d under the caged and uncaged conditions, respectively. This suggests the potential of cage farming of *K. alvarezii* in Silaqui Island, Bolinao, Pangasinan.

Based on experience in this study, some *K. alvarezii* propagules tied to mono-lines were dislodged by strong wind and water current. The plastic straw used to attach the propagules to the mono-lines may have weakened and torn apart due to the increasing weight of the seaweeds and the strong surface water movement during the study. However, in the caged raft, the dislodged propagules were still recovered and replanted because they merely settled down at the bottom of the net. This further suggests that cage draft could be used in *K. alvarezii* farming in Silaqui Island because it could maximize production by preventing the stocks from being lost as in the uncaged condition. It should be noted that the present study was conducted during the peak of the northeast monsoon, which is characterized by strong water movement in the area.

Diseases and Other Health Problems of *K. alvarezii*

Table 2 shows the diseases and other health problems observed in *K. alvarezii* in the two treatments.

Epiphytism of unknown species were found growing in some thalli of the seaweed in the two treatments (Figure 3). Epiphytes were already present in *K. alvarezii* before they were planted in the mono-lines, as observed in the BML outdoor hatchery where they were sourced. According to the BFAR poster, the main cause of epiphytism was slow water movement.

Table 2. List of diseases and other health problems observed in *K. alvarezii* in the two treatments.

Disease/Health Problem	Caged	Uncaged
Epiphytism	+	+
Ice-Ice	+	+
Pitting	+	+
Tip Darkening	+	+
Tip Discoloration	+	+

(+) indicates the presence of the disease/health problem

Figure 3. Epiphytes (encircled) observed in some thalli of *K. alvarezii*.

Ice-Ice disease was observed in *K. alvarezii* in the two treatments during the second week of culture. This disease is characterized by the paling or whitening of thallus of *K. alvarezii*. The affected part became soft and fragmentation ultimately occurs, causing the affected parts to break off (Figure 4).

Figure 4. Fragmentation of thallus of *K. alvarezii* due to ice-ice disease.

Small cavities in some thalli of *K. alvarezii*, known as pitting (Figure 5), were also observed in the two treatments during the third week of culture. Pitting eventually occurs when the *K. alvarezii* had survived from ice-ice disease (BFAR poster). However, pits were still sites of growth of new branches of *K. alvarezii* and appeared not to adversely affect the growth of the seaweed.

Figure 5. Occurrence of pitting (encircled) in the thallus of *K. alvarezii.*

Almost all *K. alvarezii* propagules in the two treatments were affected by tip darkening starting from the second week of culture (Fig. 6). Tips turned into dark blackish ones. Tip darkening may be due to the cold weather (BFAR poster) as the study was conducted during the months of November to January which were the coldest months in the Philippines and as evidenced by low temperature observations (26.20-28.55°C) in the present study.

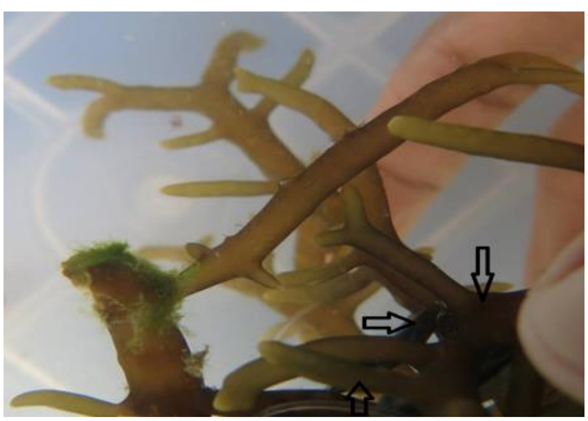

Figure 6. Darkening of some tips (arrows) of *K. alvarezii.*

Some tips of *K. alvarezii* in the two treatments turned whitish in color. This health problem was known as tip discoloration (Fig. 7). Wide-scale prevalence of tip discoloration was observed during the third week of the culture period. In this particular week when the two rafts turned upside down caused by huge waves and strong winds during the typhoon "Ruby", some parts particularly the tips, of *K. alvarezii* were exposed to the air for an unknown period of time, causing the exposed parts to turn whitish.

Figure 7. Discoloration of some tips (arrows) of *K. alvarezii.*

Effects of Fish Grazing

Fish grazing incidence was not observed to occur in the present study, even in the uncaged, open water condition. This may be because of the seasonality of abundance of fish grazers particularly the species of siganids or rabbitfishes. These fishes usually have high rates of grazing during the juveniles and sub-adult stages, when they are also known to form grazing schools (R.D. Villanueva, personal communication).

Though there had been limited published study on the seasonality of abundances of the different life stages of siganids in Bolinao, a glimpse of this can be obtained from a provision in the Bolinao Coastal and Fisheries Resources Management Ordinance of 1999. The section on "Closed Season in the Gathering of Barangen and

Padas" states that "there shall be a closed season in the gathering of padas or siganid fry during the month of April." Following this line of information, siganid juveniles and sub-adults abound during the succeeding months (May to July) – the months when there is an expected high grazing pressure on seaweed resources (including farmed eucheumatoids). Apparently, the study was not conducted during these months. Hence, limited, if any, grazing was observed in this study.

Other fish species were also observed particularly in the caged raft that passed through some holes in the net, such as a longhorn cowfish (*Lactoria cornuta*), floral blenny (*Petroscirtes mitratus*), and unidentified shrimp species. However, these species were not observed to graze on the cultured seaweed.

Water Quality Parameters

The recorded 48-h temperature range in Silaqui Island on 13-15 January 2015 ranged from 26.20 to 28.85°C, which was found ideal for the growth of *K. alvarezii*. The temperature for optimal growth of *K. alvarezii* ranges from 26 to 30°C [8], which may explain the high growth rates of *K. alvarezii*, both in the caged and uncaged conditions of the present study.

The average recorded salinity of seawater was 34 ppt. It was reported that *K. alvarezii* grows best in full salinity seawater [9]. At most successful farm sites, salinity ranges from 30-35 ppt. Salinities less than 20 ppt induces whitening of short segments in the mid-branches of *K. alvarezii* under laboratory conditions [10]. Since the recorded salinity in the present study was normal, other ecological factors like light intensity may trigger the occurrence of ice-ice disease in *K. alvarezii* [11]. These authors suggest that the whitening phenomenon in seaweeds is caused by both abiotic and biotic factors acting in combination [11]. When the seaweed is under stress, it emits a moist organic substance that attracts bacteria in the water and induces the "whitening" and hardening of the seaweed branches. Uninfected parts remain healthy while infected ones undergo depigmentation and eventually lead to plant breakage by any force of nature.

The average recorded light intensity in this study was 14.96 micromoles photon m^{-2} s^{-1}. This was lower than the results in another study under laboratory conditions [10]. In that study, the authors reported that light intensity of less than 50 micromoles photon m^{-2} s^{-1} had induced ice-ice disease in *K. alvarezii* under laboratory conditions. Other factors (biotic and abiotic) may also contribute to the occurrence of ice-ice disease [11].

In terms of water movement, results showed no significant difference in the water movement inside the caged and uncaged raft, based on the diffusion indices of clod cards deployed in each raft. The diffusion indices in caged and uncaged raft were 11.44 and 10.06, respectively, with no statistical difference ($P>0.05$). The slightly higher diffusion index in the caged condition may be because the direction of the surface current was towards the caged raft. One of the requirements for *K. alvarezii* culture was high degree of water motion [6]. This suggests that Silaqui Island is an ideal site for commercial cultivation of *K. alvarezii*.

CONCLUSION AND RECOMMENDATION

Based on the results of the study, we can conclude that the growth of *K. alvarezii* under caged and uncaged conditions was similar and that the water quality in Silaqui Island was ideal for cultivation of this seaweed. However, future studies of this kind need to be done at other times of the year (i.e. April to July) to take into consideration the effect of fish grazing. However, fish grazers do not abound in the area during the months of November to January. It is recommended to put an enclosure around the raft to protect against loss of stocks during adverse weather conditions as it does not significantly affect the growth of *K. alvarezii* and the water movement which is desirable for seaweed culture. The net will also serve as an additional barrier to fish grazing.

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