Aquaculture Reports 6 (2017) 49–55

Contents lists available at ScienceDirect

Aquaculture Reports

journal homepage: www.elsevier.com/locate/aqrep

Comparison growth of *Kappaphycus alvarezii* (Rhodophyta, Solieriaceae) cultivation in floating cage and longline in Indonesia

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ARTICLE INFO

Keywords:
Kappaphycus alvarezii
Floating cage
Propagule
Cultivation
Herbivorous

ABSTRACT

Currently, cultivation using cages for *Kappaphycus alvarezii* was limited reported before. This study aims to reveal growth of *K. alvarezii* cultivated in floating cages and longline. The study was conducted in one of cultivation areas in Southeast Sulawesi, Indonesia. Total gross weight, propagule growth rate and specific growth rate were performing in this study. During our field experiment, total gross weight of *K. alvarezii* after 40 days, from 5 kg was growth to 22.5 ± 1.40 kg and 38.8 ± 1.6 kg on longline and floating cages, respectively. Propagule growth rate after 40 days, from 50 g was 107.8 ± 7.0 g and 152.5 ± 7.9 g during April, and 132.0 ± 8.0 g and 218.8 ± 8.6 g during August, on longline and floating cage, respectively. Specific growth rate of *K. alvarezii* was high during August, 2.43% day^{-1} and 3.69% day^{-1} cultivated in longline and floating cage, respectively. Propagule morphology was white and damage in 40% cultivated by longline and no damage by using floating cage particular in August and September while high dense of herbivorous fish surrounding the experimental sites.

1. Introduction

Kappaphycus alvarezii cultivation has developed since the demand for raw materials of carrageenan from industries increased rapidly in many countries, particularly in Southeast Asia. This spurred the development of seaweed production rapidly and provides expectations for the improvement of farmer's life. *K. alvarezii* started to cultivate in Philippines and Fiji since 1970 and 1971 (Doty and Alvarez, 1973; Doty, 1973; Parker, 1974; Prakash, 1990; Luxton et al., 1987), and after 1980 it has started developed in any other country such as in, Indonesia, Tuvalu Malaysia, Maldives, India, Tanzania, Vietnam, Brazil, and Venezuela (Gentle, 1990; Doty, 1973; Adnan and Porse, 1987; Luxton, 1993; Wu et al., 1988; Tanaka, 1990; Smith, 1990; Lirasan and Twide, 1993; Ohno et al., 1996; de Paula et al., 1999; Rincones and Rubio, 1999).

Cultivation methods commonly used by raft bamboo and recently was developed into a longlines method. Longline method has been used in some countries such as Philippines, known as tie–tie (Azanza-Corales, 1990; Ask and Azanza, 2002). Most farmers in several countries applied longline methods for seaweed cultivation such as Indonesia, India, Malaysia, India, Tanzania, Vietnam, Brazil, Kenya and Madagascar (Luxton, 1993; Lirasan and Twide, 1993; Luxton et al., 1987; Bindu, 2011; Mollion and Braud, 1993; Ohno et al., 1996; Hayashi et al., 2007; Ask and Azanza, 2002). Cultivation method of *K. alvarezii* in Indonesia started since 1985 with a bamboo raft and developed into longline since 1992. Now, longline method is being developed by farmers extensively. Longline method provides open access to some herbivorous fish. Recently, various problems appear due to herbivorous fish continue grazing the *K. alvarezii* (Kasim and Asnani, 2012; Kasim et al., 2016). In 2013 a new cultivation method using floating cages started by a small part of farmers in eastern Indonesia, especially in Southeast Sulawesi. This method is an alternative in order to protect the seaweed of various herbivores (Kasim et al., 2016).

This study tries to explore the different of growth rate of *K. alvarezii* cultivated on longline as open access methods from various herbivores fish and floating cage as protective method from various herbivores.

2. Material and methods

2.1. Study sites

This study was conducted in one of the largest seaweed cultivation areas in Southeast Sulawesi, namely Lakeba coastal area, Bau-Bau (50 48′78.2″ N, 122 056′26.3″ E), Southeast Sulawesi, Indonesia. This field experiment performs during April–November 2014. The area covered by sand and several rubble corals with spread seagrass and seaweeds. The depth during low tides is 1 m and high tide is 5 m.

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http://dx.doi.org/10.1016/j.aqrep.2017.03.004
Received 22 February 2016; Received in revised form 25 January 2017; Accepted 28 March 2017

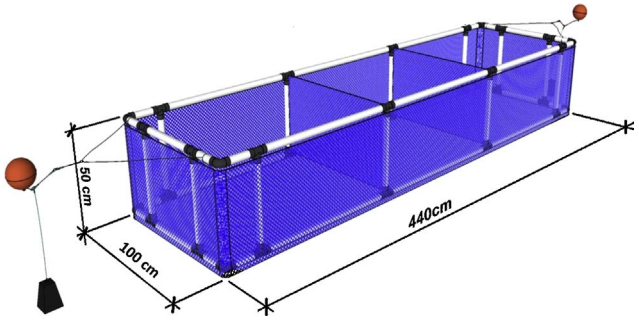

Fig. 1. Floating cage was used on this experiment.

2.2. Field experiment

To explore the different of growth rate in this experiment, floating cages and longline were used. The floating cage used was a strung confinement of PVC pipe and a box with a dimension of 100 cm × 440 cm × 50 cm. The outer wall of the cage was wrapped with multifilament nets with a diameter of 1 cm (Fig. 1). The floating cages were designed to be partially in the water and a small portion of it remains on the surface of the water. The depth of the submerged part of the cage was 50 cm. Number of floating cages used were 15 units. 3 units of cages with 3 replicate (9 cages) were conducted to explore the total gross growth rates. Each cages were performing with same first weigh (W_o = 5 kg). 3 units with 2 replicate of cages (6 cages) were used for clarify monthly propagule growth rates and specific growth rate (SGR) with same first weight in each month (50 g).

For comparison method with longline, 6 units of longline were used in this experiment. Longline designed from PVC pipe and long ropes. There are two PVC pipes on two different sides. Each side has one the pipe with a length of 5 m. between one pipes with other pipes, there is a rope with a length of 10 m. Distance between one rope with other rope is 100 cm (Fig. 2). On one unit there are 10 rope used to tie the seeds. Distance of *K. alvarezii* seed tied at the rope is 25 cm so that in one unit contained total 25 kg fresh weight of *K. alvarezii.* The experiment for growth rate of total in kg was performing in 3 replicate with same first fresh weight (5 kg) that are used in floating cage. Each replicate was sign with different color of line (Fig. 2). The experimental of floating cage and longline were conducted in one cultivation areas with same of environmental parameters.

This experiment was conducted by calculating the specific growth rate (SGR) of propagule of *K. alvarezii* in seven cultivation periods each one with 40 days cultivated during April–November. SGR was presented as percentage growth per day using the formula of Luhan and Sollesta (2010):

$$SGR=(\ln W_t/\ln W_o)/t \times 100\%$$

where SGR = specific growth rate (% in wet weight per day), W_t = weight after t days; W_o = initial weight; t = time in days.

To find out the effect of floating cage on preventing *K. alvarezii* from herbivorous, three units of floating cage were put in different places with high possibility of availability of herbivores fish. We are also performing three units longline at three different site just near the location of floating cage. In order to find out the effect of herbivorous fish on propagule of *K. alvarezii*, this research was done by observing the morphology and shape of propagule in a floating cage and longline. To observe the fish activity surrounding the floating cage and longline, a digital underwater camera (video recording) was placed at bellow of floating cage and near the longline methods (farmer's owner) in 6 h during day time (3 h during 08.00–11.00 am and 3 h during 14.00–17.00 pm). This experiment was done by observe the fish activity, fish species, fish number, fish grazing and by looking morphology and shape of the thallus of *K. alvarezii* scattered in a floating cage. To investigates of fish grazing we were performing by investigating of fish gut content. Fish population was performing by belt transect analysis (English et al., 1997).

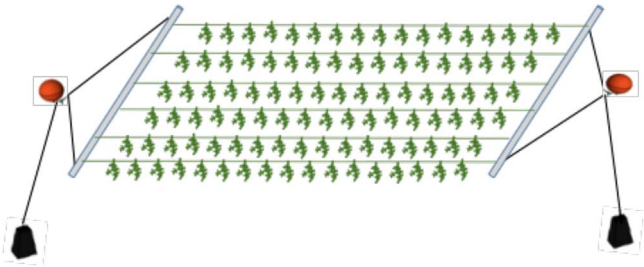

Fig. 2. Longline was used on this experiment.

2.3. Environments parameters

Seawater parameters were measured in situ by using the suitable equipment such as thermometer for temperature, refractometer for salinity, and current meter for current velocity. Every measurement was done in every 5 days in day time and night time. Total (dissolved) nitrogen and phosphorus in water around the cages were determined spectro-photometrically according to the methods described by Strickland and Parson (1972).

2.4. Statistical analysis

The wet weight of *K. alvarezii* was calculated in term of mean ± standard deviation. In addition, coefficient correlation was calculated for growth rates determined for 40 days growth times and environmental parameter. To find out different between *K. alvarezii* where cultivated by floating cage and longlines for 40 days, by Mann–Whitney Z test (running on http://www.socscistatistics.com/). Correlation coefficients between growth rate and environmental factors were calculated using simple linear models (Pearson's r). Statistical analyses were performed using the SPSS package.

3. Results

Total gross weight in kg was observed during 40 days. During the cultivation periods, the growth of *K. alvarezii* increased from 5 kg to 22.5 ± 1.40 kg by using longline and from 5 kg to 38.8 ± 1.6 kg by using floating cage (Fig. 3).

Propagule growth rate of *K. alvarezii* was observed monthly and in 40 days with first weight (W_o) 50 g. The growth rate of *K alvarezii* during August was high 132.0 ± 8.0 g on longlines and 218.8 ± 8.6 g in floating cage and low in April was 107.8 ± 7.0 g on longline and 152.5 ± 7.9 g on floating cage (Fig. 4).

During June, July and August, specific growth rate (SGR) of *K. alvarezii* was 3.52% day^{-1}, 3.53% day^{-1}, 3.69% day^{-1} cultivated on floating cage and 2.41% day^{-1}, 2.90% day^{-1}, 2.43% day^{-1} cultivated on longline, respectively (Fig. 5). Despite there are significant different in SGR of *K. alvarezii* cultivated during June–November between floating cage and longline were analyzed by Mann–Whitney Z test with $Z = -2.811$, considering confidence interval of 95% ($p \leq 0.05$).

During August–September, from our video recording of herbivorous fish activity there are 62 fish in average was count in every 5 min and only 8 fish at surrounding floating cage. In one seedling of *K. alvarezii* there are 40% of seedling part was white and damage at longline and there is no damage of seedling in floating cage instead several part of seedling was going out surrounding net of floating cage (Fig. 6A and B).

Environmental factors observed during our experiment were related to the growth rates of *K. alvarezii*. During June and August, the current velocity was high particular in evening (4 pm) 0.089 and 203 m/s. Temperature was 25 °C in June and December and 31 °C during September. Salinity was range from 29–32‰. Nitrate concentration