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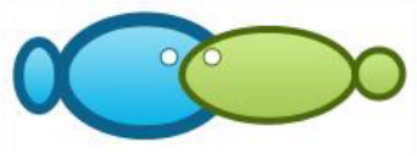

# Effect of seaweed *Kappaphycus alvarezii* aquaculture on growth and survival of coral *Acropora muricata*

[1]Sri Mulyani, [2]Ambo Tuwo, [2]Rajuddin Syamsuddin, [2]Jamaluddin Jompa

[1] Department of Fisheries, Faculty of Agriculture, Bosowa University, Makassar South Sulawesi, Indonesia; [2] Faculty of Fisheries and Marine Science, Hasanuddin University, South Sulawesi, Indonesia. Corresponding author: S. Mulyani, smjournal45@gmail.com

**Abstract**. The cultivation activity of seaweed *Kappaphycus alvarezii* may threaten the coral reefs. This study aimed to describe the effect of *K. alvarezii* seaweed cultivation activities on the growth and survival of coral *Acropora muricata*. The study was conducted using floating seaweed cultivation at two different water depths; 2 m and 5 m with space cultivation of 10 cm, 20 cm, 30 cm and control for each station. The results showed that the highest growth rates of stations I, II, and III (0.033±0.0020 cm, 0.040±0.0011 cm, 0.052 cm±0.0004), respectively and 0.052 ± 0.0004 cm in the control (2 m depth). While the lowest at stations I, II, and III (0.014±0.0014 cm, 0.019±0.0003 cm, 0.022±0.0005 cm) respectively, with the space of 10 cm at depth of 2 m. Two cultivation treatments with spacing and depth significantly affected the growth rate of *A. muricata*. Even though 5 m depth showed 100% of the survival rate of coral, the cultivation of *K. alvarezii* at depth level the coral reef ecosystem at a depth of 2 m negatively effect on *A. muricata* compared to 5 m.

**Key Words**: coral reef, growth rate, seaweed culture, spacing, depth.

**Introduction**. Coral reefs play ecological role for many marine species which becomes habitat, nursery and feeding ground for many marine species (Burke et al 2002). Coral reefs also serve as a natural barrier for the shoreline and small islands from waves.

Although the coral ecosystem highly contributes to the fisheries sector, it is also a complex and fragile ecosystem. Some disturbance, such as human anthropogenic, cultivation activity, mariculture activity, and water pollution may lead to ecosystem damage and habitat loss for many marine species (Wilkinson 2000). Recently, the negative effects of seaweed aquaculture on the coral reef ecosystem become a problem. However, there is no empirical data which addressed the adverse effect of seaweed cultivation on the coral reef. Nonetheless, several studies on the growth of Acropora species in Indonesia have been documented. The average growth rate of *Acropora muricata* species ranged from 0.67 to 1.00 mm in Goba of Pari Island, Indonesia (Manullang 1995). Johan (2000) reported that the length of the coral growth of *A. muricata* was 0.374 cm per month.

Several suggestions have been presented in various seminars to regulate culture methods for seaweed such as buffer zone and depth of culture techniques, therefore, the present study aimed to investigate the effect of seaweed *K. alvarezii* culture on the growth and survival of coral *A. muricata*.

## Material and Method

***Study location***. The study was conducted in the waters of Laikang gulf, Garassikang village, West Bangkala subdistrict, Jeneponto regency, South Sulawesi Province.

***Study design***. A completely randomized design with 3 x 2 x 4 factorial was applied for experimental design. The treatment culture for seaweed consisted of two differences depth level; 2 m and 5 m and spacing treatments of 10 cm, 20 cm, 30 cm and control,

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using floating monoline method for three stations. A total of 24 units of study (18 units of cages and 6 units of the coral reef ecosystem research without seaweed culture on as control) were used. On each clump rope was placed *K. alvarezii* seed with initial weight of 50 g per clump.

***Research equipment***. The equipment and materials for measuring coral growth of *A. muricata* are shown in Table 1. The materials for floating rafts consisted of bamboo, plastic rope PE (ϕ 2 mm, 6 mm and 10 mm), stakes wood and anchors.

Table 1

Equipment and materials used in the process of collecting data on the growth rate of coral

| *Equipment* | *Materials* | *Description* |
|---|---|---|
| Scuba diving | | One complete set Mares in brand |
| Caliper | Iron | Iron made with a precision of 0.01 cm |
| Underwater camera | | Canon A6450 (10 megapixel) + additional watertight container |
| Water paper and belt | Paper | Waterproof paper as much as 25 sheets |
| Work board and 2B pencil | Wood | Wood made |
| Plastic basket | Plastic | To place the underwater writing slate board |

***Parameter measurements***. Measurement of coral growth parameters was performed using calipers (Figure 1). It was done by measuring the coral height perpendicularly from coral branch straps until the highest branch of coral (Figure 1).

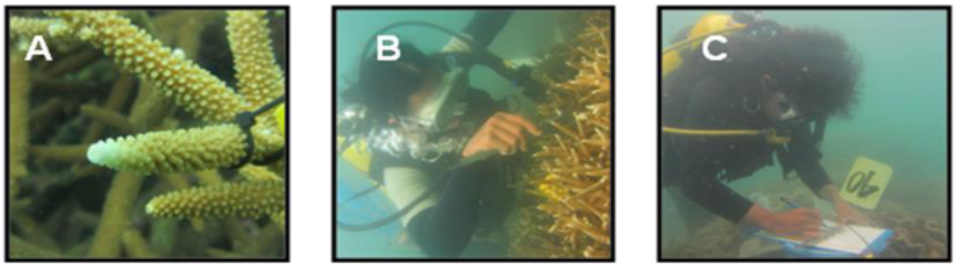


Figure 1. (A) Coral *Acropora muricata*, (B) Measurement of coral *A. muricata*, (C) Underwater data recording.

For each treatment unit, corals were observed as each of 5 branches of *A. muricata* to be numbered were made from plastic and attached to the measured coral branches which was carried out in water depths of 2 m and 5 m.

Measurement of coral growth rate parameter *A. muricata* was carried out every two weeks in the study location. The average growth rate of coral (Coral branching (CB)) *A. muricata* was calculated using the following formula:

$$P = (Lt - Lo) / t$$

Where:
P = Coral growth achievement (cm per cycle)
$L_t$ = Height average at the end of study (cm)
$L_0$ = Height average at the initial of study (cm)
t = Observation time

The coral survival was obtained by comparing the number of individuals living coral at the end of the study with the number of individual corals at the beginning of the study.

The formula used to calculate the survival rate as follows:

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The formula used to calculate the survival rate as follows:

$$S = \frac{N_t}{N_o} \times 100\%$$

Where:
S = Survival (%)
$N_t$ = Total coral individual live at the end of study
$N_o$ = Total coral individual at the initial of study

Physical and chemical parameters of waters measured included: light intensity, sedimentation, nitrate, orthophosphate, ammonium, Ca and Mg (Table 2).

Table 2
Physical and chemical characteristics of measured waters, equipment/ methods of measurement and references used

| *Parameters* | *Units* | *Equipment/Measurement method* | *References* |
|---|---|---|---|
| Light intensity | Lux | Lux meter | APHA 2005 |
| Sedimentation | $mg/cm^2/day$ | Trap sediment | APHA 2005 |
| $NO_3^{2-}$ | ppm | Spectrophotometry | APHA 2005 |
| $NH_4^+$ | ppm | Spectrophotometry | APHA 2005 |
| $PO_4^{3-}$ | ppm | Spectrophotometry | APHA 2005 |
| $NH_4^+$ | ppm | Spectrophotometry | APHA 2005 |
| Ca | ppm | Titration | APHA 2005 |
| Mg | ppm | Titration | APHA 2005 |

***Statistical analysis***. Coral growth data were analyzed using ANOVA with factorial (two-factor). If the treatment was influential on the variable, was followed up with a W-Tukey test using SPSS ver. 16 for Windows. To know the differences of coral growth variable both in cycles or among stations, the data were analyzed by t-test (independent-samples t-test and Paired-samples t-test) using SPSS version 16 for Windows. Multiple linear regression analysis was applied for obtaining the correlation between planting distance and the water depth (independent variables) on the growth rate of coral *A. muricata*, using multiple linear regression analysis.

## Results

***The growth rate of coral***. The result of measurement for growth rate of coral *A. muricata* at three stations during the study is presented in Figure 2. The measurement results of growth rate of coral *A. muricata* showed an increase coral daily growth rate until the end of the study (Table 3). The lowest growth rate of corals was found at 10 cm spacing treatment in depth of 2 m (0.014±0.0014 cm per day) and the highest growth rate was obtained from control seaweed culture (0.053±0.0018 cm per day).

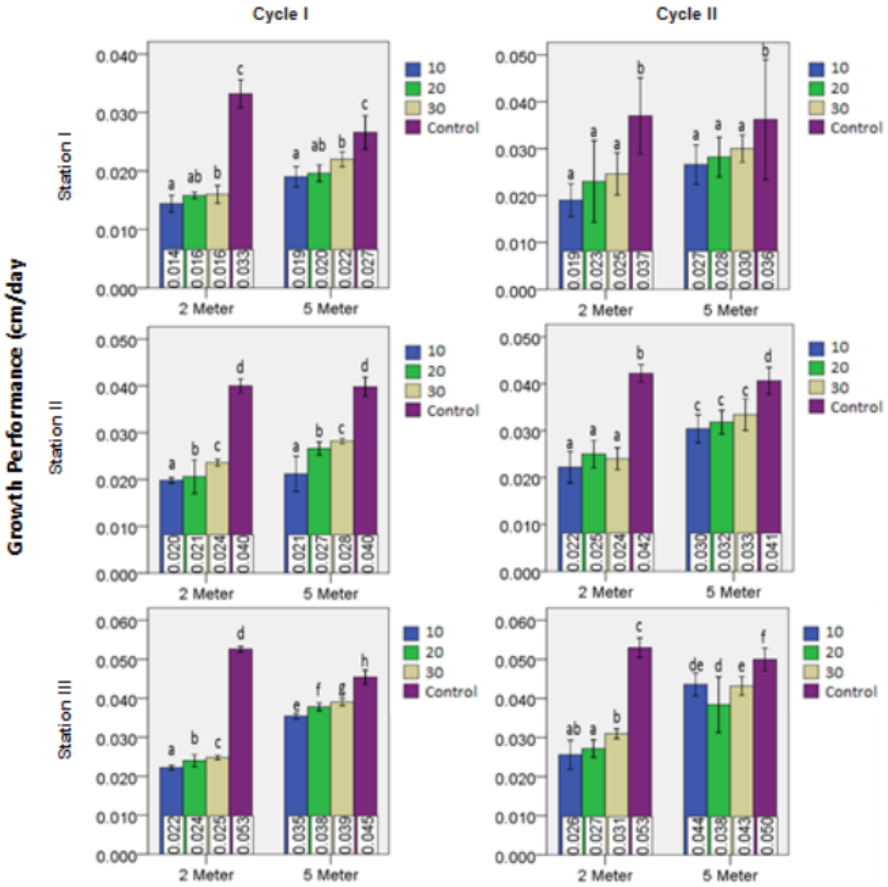


Figure 2. The growth rate of coral *Acropora muricata*.

Table 3

The growth rate of coral *Acropora muricata*

| *Planting treatment* | | *Average of coral growth rate ± SD* | | |
|---|---|---|---|---|
| *Distances* | *Depths* | *Station I* | *Station II* | *Station III* |
| 10 cm | 2 m | 0.014±0.0014[a] | 0.019±0.0003[a] | 0.022±0.0005[a] |
| 20 cm | 2 m | 0.016±0.0004[ab] | 0.021±0.0030[b] | 0.024±0.0010[b] |
| 30 cm | 2 m | 0.016±0.0011[b] | 0.024±0.0006[c] | 0.025±0.0005[c] |
| Control | 2 m | 0.033±0.0020[c] | 0.040±0.0011[d] | 0.052±0.0004[d] |
| 10 cm | 5 m | 0.019±0.0013[a] | 0.021±0.0029[a] | 0.035±0.0004[e] |
| 20 cm | 5 m | 0.020±0.0012[ab] | 0.027±0.0008[b] | 0.038±0.0005[f] |
| 30 cm | 5 m | 0.022±0.0009[b] | 0.028±0.0005[c] | 0.039±0.0006[g] |
| Control | 5 m | 0.027±0.0025[c] | 0.040±0.0016[d] | 0.045±0.0013[h] |

Different letters in the same column indicates significant differences between treatment (spacing) at the confidence level of 5% (P <0.05).

The growth rate at each station has a value which tends to increase in accordance with the treatment, where the highest growth rate of coral samples obtained from non-cultivation areas for seaweed culture (control) for station I, II, and III at a depth of 2 m with a value of growth rate of 0.033±0.0020 cm, (0.040±0.0011 cm, and 0.052±0.0004 cm respectively. The lowest growth rate was obtained for station I, II, and III from seaweed cultivation areas with spacing treatment of 10 cm at a depth of 2 m with value

| | | | | |
|---|---|---|---|---|
| 20 cm | 5 m | 0.020±0.0012[ab] | 0.027±0.0008[b] | 0.038±0.0005[f] |
| 30 cm | 5 m | 0.022±0.0009[b] | 0.028±0.0005[c] | 0.039±0.0006[g] |
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of growth rate of 0.014±0.0014 cm, 0.019±0.0003 cm, and 0.022±0.0005 cm respectively.

The growth rate of coral in non-seaweed cultivation areas was better than the coral growth rate from seaweed cultivation areas. The growth rate of coral at the station I showed no significant differences ($P>0.05$) between the spacing treatment 10 cm and 20 cm, however, a significantly different ($P<0.05$) was found between the treatment 30 cm and control. At station II, all treatments showed significant differences ($P<0.05$). While, at station III with the spacing treatment of 20 cm and 30 cm showed no significant differences ($P>0.05$). However, a significantly difference ($P<0.05$) was found between spacing treatment of 10 cm and control.

The growth rate of coral *A. muricata* for each station tend to increase along with the increase of spacing and depth. The highest growth rate of coral was obtained from a depth of 2 m group.

***Coral survival***. Percentage of coral *A. muricata* survival at the end of study in each treatment was 100% in both culture and control.

***The relationship between distance and depth culture with the growth of coral A. muricata***. The results of multiple regression analysis with a backward method in SPSS analysis showed that relationship between the growth rate of coral *A. muricata* with the correlation coefficient (r) for planting distance treatment was 0.6107. It is indicated as positive and moderate correlation. The regression equations were as follows:

$$Y = 0.0054\ x + 0.0142$$

Where: Y = growth rate of coral
x = spacing

The relationship between the growth rate of coral *A. muricata* and depth treatment was indicated by a correlation coefficient r of 0.082 which was categorized as positive and low correlation with regression equations as follows:

$$Y = 0.002\ x + 0.025$$

Where: Y = growth rate of coral
x = depth

**Discussion**. At a depth of 2 m planting treatment of seaweed, the sediment was deposited into the bottom of the water. However, at a depth of 5 m, the deposited sediment was reduced due to water current in both seaweed *K. alvarezii* and coral *A. muricata*. Philip & Fabricius (2003) claimed that the deposition of anthropogenic sediment adversely affect the photosynthetic activity of zooxanthellae and the corals viability.

In the seaweed cultivation area, at a depth of 2 m of coral reef ecosystems, the growth rate of coral was lower than in a depth of 5 m due to environmental pressure or high sedimentation. The corals can only tolerate the high turbidities which time duration from several days or at least 5-6 weeks. Nevertheless, the increases of sedimentation lead to smothering, tissue necrosis, burial of coral polyps, and shading. Moreover, the population explosion of bacteria often was found in coral mucus. The fine sediments have a greater impact on corals growth than coarse sediments (Erftemeijer et al 2012).

Differences in light intensity can lead to differences in the abundance of zooxanthellae found on coral colonies, where the increase in light intensity directly proportional to the increase in the abundance of zooxanthellae (Fachrurrozie et al 2012). Moreover, Warner et al (2002) stated that the physiology of zooxanthellae is highly affected by intensity of light and water temperature. In addition, the number of cell zooxanthellae in the coral reefs is higher during the rainy season, but the pigment of photosynthetic activity is higher during the dry season (Costa & Amaral 2000). The 90% of energy from photosynthesis in zooxanthellae is provided for polyps requirement

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(Leletkin 2000). Zooxanthella requires sufficient sunlight for photosynthesis to produce calcium carbonate that affect coral growth rate (Rani et al 2004). Secondly, the deposit of sediment on colonies cause corals release a lot of energy to clean of these sediments, most of corals energy is allocated for metabolism process and feeding activity. Due to loss of energy, coral growth can be inhibited leading to reduced photosynthetic ability due to sedimentation. Photosynthesis is an important factor in supporting the growth of algae and tissues. When the photosynthesis process is disrupted it may affects the growth rate of algal cell division. Corals obtain most of their energy and nutrients in two ways, such as, through photosynthesis mechanism by zooxanthellae or directly zooplankton capture from the water column (Lesser 2004).

Sedimentation is also a major factor that resulted in the death of corals during the recruitment process through smothering mechanism (Febricius et al 2003). Conditions of stress to corals caused by sedimentation can also be seen from the decrease in the density of zooxanthellae and chlorophyll concentrations in the tissues of coral polyps (Brown et al 1999).

Each coral species have different abilities to adapt to the presence of sediments (Rogers 1990). McLaughlin et al (2003) stated that suspended sediment or deposited is generally known to have a negative effect on reef communities. Effects of sedimentation on the reef can cause bio-erosion by various macroboring organisms such as sponges, worms, bivalve (Zaenuri et al 2016).

Survival of coral *A. muricata* in the present study was high. The nature of zooxanthellae is high durability and plasticity (Hill et al 2009). Therefore zooxanthellae can adapt quickly in an environment that is less favorable.

**Conclusions**. The seaweed *K. alvarezii* culture on the coral reef ecosystem at depth of 2 m adversely affect to the growth of coral *A. muricata* than depth of 5 m. Seaweed *K. alvarezii* cultivation which used 10, 20 and 30 cm of planting distance treatment, a depth of 2 m and 5 m did not cause mortality of the *A. muricata* coral. A depth of 2 m is recommended for seaweed cultivation.

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Authors:
Sri Mulyani, Bosowa University, Faculty of Agriculture, Department of Fisheries, Indonesia, South Sulawesi, Makassar, 90231, e-mail: smjournal45@gmail.com
Ambo Tuwo, Hasanuddin University, Faculty of Marine Science and Fisheries, Indonesia, South Sulawesi, 90245, e-mail: ambotuwo62@gmail.com
Rajuddin Syamsuddin, Hasanuddin University, Faculty of Marine Science and Fisheries, Indonesia, South Sulawesi, 90245, e-mail: rajuddinsyamsuddin@yahoo.com
Jamaluddin Jompa, Hasanuddin University, Faculty of Marine Science and Fisheries, Indonesia, South Sulawesi, 90245, e-mail: jamaluddin.jompa@gmail.com

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Authors:
Sri Mulyani, Bosowa University, Faculty of Agriculture, Department of Fisheries, Indonesia, South Sulawesi, Makassar, 90231, e-mail: smjournal45@gmail.com
Ambo Tuwo, Hasanuddin University, Faculty of Marine Science and Fisheries, Indonesia, South Sulawesi, 90245, e-mail: ambotuwo62@gmail.com
Rajuddin Syamsuddin, Hasanuddin University, Faculty of Marine Science and Fisheries, Indonesia, South Sulawesi, 90245, e-mail: rajuddinsyamsuddin@yahoo.com
Jamaluddin Jompa, Hasanuddin University, Faculty of Marine Science and Fisheries, Indonesia, South Sulawesi, 90245, e-mail: jamaluddin.jompa@gmail.com

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