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Research Article
Growth Rate and Carbon Absorption of Coral Transplantation by the Binding and Gluing Methods at Taman Nirwana

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Abstract

Background and Objective: The gluing method has good prospect to the growth of transplanted coral if compared to the regular binding method. This study aimed to determine the differences in growth rates between transplanted corals with these two methods. **Materials and Methods:** Coral seedlings used in this study were about 70-129 mm in size, taken from the branching life form of *Acropora* genera. Coral transplantation were mediated through regular the binding method and the gluing method, before the experiment result statistically tested with Mann-Whitney test. The experiment consisted of 2 treatments and 20 replicates. **Results:** The absolute growth rate, the monthly growth rate and the branching rate of transplanted coral between the two methods were not different ($p>0.05$). On the other hand, the survival rate and quantitative carbon absorption of corals transplanted with gluing method were observed better than those with binding method. All transplanted corals through gluing method survived, while those transplanted with binding method survived 95% (19 living corals from initial 20 observed samples). The gluing transplanted corals averagely absorbed carbon as much as 23% (11.38 mg L^{-1}), while the other method absorbed only 18% (8.99 mg L^{-1}). **Conclusion:** There is no significant difference of the growth rate between gluing transplanted corals and binding transplanted coral, however, the first method showed better survival rate and the carbon absorption than the later.

Key words: Binding method, gluing method, coral transplantation, carbon absorption

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

West Sumatra province in Indonesia has an approximately 53,515 km^2 of coral reef ecosystem, with 66.58% of this area considered as damaged[1]. The destruction is due to the fishing with explosives and poison, careless anchoring, sedimentation, industrial wastes and collecting corals for souvenirs as well as raw material for buildings[2,3].

The damaging of coral reefs contributes to the rising of global surface temperature, the rising of sea levels, reduced carbon absorption[4,5], severing fishery sector[6,7] and the increasing of abrasion on the coastal areas. In west Sumatra, these presumed repercussions can be observed in Tiku beach of Agam Regency, in Sasak beach of west Pasaman Regency, in Pariaman, Padang Pariaman and Mentawai Archipelago[8,9]. Furthermore, a devastated coral condition can be observed in Nirwana beach, Padang city, while the corals in front of mangrove zone is considerably intact, those around the tourism zone has been severely damaged, even those in adjacent to the settlement zone are completely djminished[10].

One known technique to rehabilitate the damaged coral reefs is using coral transplantation. It is performed through transplanting or cutting live corals which are then planted in certain media before placed within the damaged areas. It accelerates the regeneration of damaged coral reefs and to some extend, able to build new coral reef colony in a non-existing coral area[9,11,12].

There are two types of methods for transplanting coral, namely; binding it to the PVC pipe and gluing it to the substrates. In general, coral transplantation is conducted by attaching pieces of coral to the substrate which then implanted underwater. However, this method often meets failure, as the coral seedlings detached, die, unable to develop, or sometimes the presence of foreign objects that in adversely impact water quality and coral growth[13]. The gluing method uses adhesive mixture that resembles the composition contained in coral body. The coral seedlings will be firmly attached to the substrate using this glue[13]. This method is believed to have better prospect in enhancing the growth of transplanted coral than using the regular binding method. Based on this thought, the research regarding coral transplantation with gluing and binding methods were carried out to order to determine the better method by comparing the growth rate and carbon absorption from each of these methods.

MATERIALS AND METHODS

Research method: The research had been carried out in the coral reef ecosystem of Taman Nirwana, west Sumatra, Indonesia (100'49"S, 100 23'22"E) from December, 2017 until June, 2018. Coral growth rate was measured through the increment of coral lengths, while the physical-chemical factors of water were taken directly in the field. The measurement of carbon absorption was conducted at the Environmental Engineering Laboratory of Andalas University.

It used an experimental method by calculating the growth rates of coral and stored carbon uptake from different transplant treatments, namely; (1) Binding method and (2) Gluing method, each with 20 replications. The parameters measured were the rate of coral length increase, number of coral branches, survival rate of coral and amount of absorbed carbon.

Making of substrates and transplant racks: The substrates were mixed between cement and gravel with ratio of 1:1. The mixture was mold in a round casting using PVC pipes 11 cm in diameter with height 5 cm. There were two substrate models used in this study. First, the one purposed for binding method, where there was a 2 cm diameter and 10 cm height PVC in the middle of the model to bind coral seedling. The model for gluing method had a depression in the middle portion with 3 cm depth and 4 cm diameter. For each type of model, 20 substrate casting were created which also served as replication in the experiment.

Rectangular shelves (racks) were made of wielded iron with $120\times100\times50$ cm^3 dimension and serves as the attachment for both substrate models. The design of the substrate models and attachment rack can be seen in Fig. 1 and 2.

Collecting coral seeds: Coral seedlings for transplant materials were taken from around study site using chisel and hammer. The coral seeds were *Acropora* genera which experiencing the branching life form. The sizes of transplants were about 70-129 mm.

Installation of seeds and transplant racks: Coral seedlings that arranged onto the racks were installed in two sessions. Each rack contained 20 substrates, with 10 substrates transplanted with binding method and another 10 with gluing method. Coral seedlings were bound into PVC pipe contained the substrate, while in the second method the seedlings were planted using coral glue. After the seedlings were properly installed on substrates, the arrangement was tied to the transplant rack using wire.

The ready racks were transported using boats and placed within the sea using SCUBA device at a depth of about 3-5 m. They were placed at the bottom of the water body, in close proximity, in order to receive similar environmental factors and minimize bias when comparing the coral growth rates.

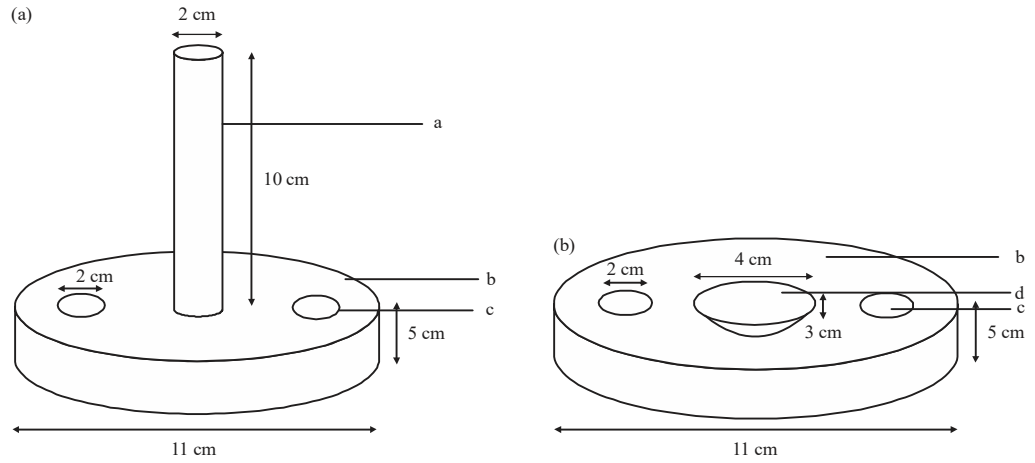

Fig. 1(a-b): (a) Substrate design for the binding method and (b) Substrate design for the gluing method
a: PVC pipe, b: Substrate, c: Binding hole, d: Basin for gluing germination

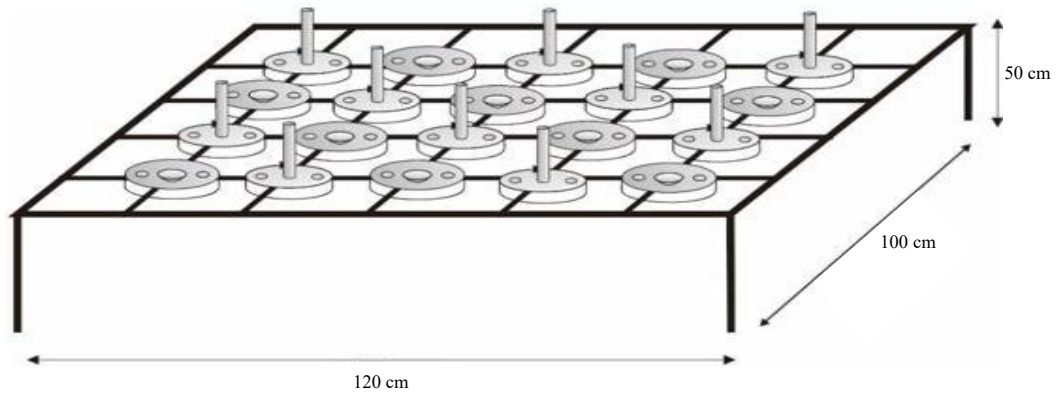

Fig. 2: Transplant rack design
a: Rack

Growth rate of coral transplantation: Coral growth rates were directly observed through measurements of the length of increments in the study site. Data then calculated using the absolute coral length increment velocity equation:

$$\alpha = Lt\text{-}Lo$$

Where:

α = Absolute coral length increment speed (mm/month)
Lt = Final length of the coral interval
Lo = Initial length of the coral interval

Survival rate: The survival rate was calculated using the Survival Rate formula as follow:

$$SR\ (\%) = \frac{N_t}{N_o} \times 100$$

Where:

SR = Survival rate (%)
N_t = Number of living coral (colonies) at the end of the study
N_o = Number of living corals (colonies) at the beginning of the study

Addition of coral branches (Counting coral branch): The counting on additional coral branches that grow at the end of the study.

Carbon absorption in coral transplantation: The carbon absorption (C) was calculated using the organic carbon content (Walkley and Black) analysis method[14] which results in percent (%) and mg L^{-1}. The calculation is performed through the following equation:

$$\text{Organic C level (\%)} = \text{ppm} \times 100 \text{ curve/mg example} \times 100 \text{ mL}/1{,}000 \text{ mL} \times \text{fk}$$

where, ppm curve is the sample level obtained from the regression curve was the relationship between the standard series level and its reading after being reduced by the blank, 100 is conversion to percentage and Fk is the water content correction factor = 100/(100-% moisture content).

Data analysis: Data analysis to determine and compare the ratio of the absolute growth rates and the coral survival rates between the two methods used Mann-Whitney statistical test[15]. Eventually, all the results were presented in tables and graphics.

RESULTS

Growth rate of coral transplants: The growth rates of coral transplants using binding and gluing methods at the coral reef ecosystem of Taman Nirwana, west Sumatra, Indonesia are shown in Table 1. The average absolute growth rate and monthly growth rate of corals transplants with binding method were 39.00±2.83 mm and 6.60±0.00 mm m^{-1}, respectively and 49.55±2.12 mm and 8.64±1.62 mm m^{-1} for gluing methods, respectively. The absolute growth rate for both methods as shown in Fig. 3, where it increased on both methods for the first 6 months. The growth rate for binding method decrease afterward for the next 3 months. The statistic test of Mann-Whitney, however, confirmed that the absolute growth rate of both methods was not significantly different between transplanting method (U = 1.16, p>0.05).

Addition of coral branches: The average increase of new coral branches during 6 months of study was 6±1.14 branches for binding method, with initial average 7±0.71and final average 13±1.41, while on the gluing method was averagely increase 12±0.71, with initial and final average 7±2.83 and 18±2.12, respectively (Table 2). Using the Mann-Whitney test, the addition of coral branches between the two methods were not significantly different (U = 1.46, p>0.05).

Coral survival rate: In Fig. 4, the survival rate from both transplanting methods are shown. With 19 living transplanted corals at the end of the study, the binding method survived 95% or its initial seedling population. The gluing method, with all of its transplanted seedling stay alive, survived with 100% rate.

Carbon absorption in coral transplantation: By quantifying the carbon (CO_2) level within the growing transplanted corals in either method, the carbon absorption can be measured and later presented in percentage and mg L^{-1} units (Fig. 5, 6). The transplanted corals through gluing method absorbed 23% carbon (value 11.38 mg L^{-1}), slightly higher than the binding method which absorbed 18% (8. 99 mg L^{-1}) carbon.

Table 1: Average initial length (Lo, mm), average final length (Lt, mm), average absolute growth rate (Lm, mm) and monthly growth average (Lmth, mm $month^{-1}$)

Treatments (n = 20)	Lo (mm)	Lt (mm)	Lm (mm)	Lmth (mm m^{-1})
Transplanted corals with binding method	101.95±5.66	140.95±7.78	39.00±2.83	6.60±0.00
Transplanted corals with gluing method	97.75±7.19	147.30±11.94	49.55±2.12	8.64±1.62

Table 2: Number of initials (Bo), final (Bt) and mean (Bm) coral branches increment of transplanted corals with binding and gluing methods

Treatments (n = 20)	Bo	Bt	Bm
Transplanted corals with binding method	7±0.71	13±1.1	6±1.14
Transplanted corals with gluing method	7±2.83	18±2.12	12±0.71

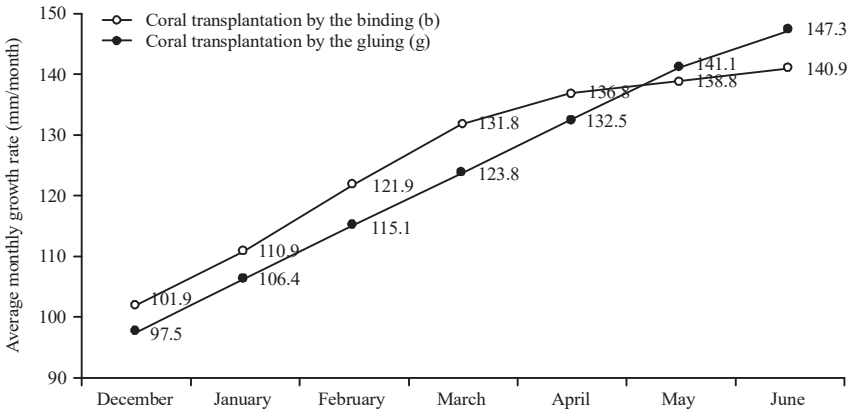

Fig. 3: Average absolute growth rate of corals transplantation (mm/month)

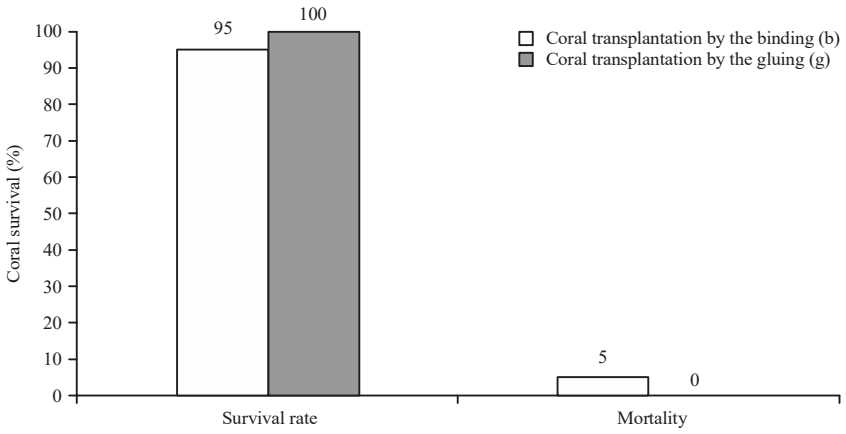

Fig. 4: Coral survival (%) and death rates of coral transplantation in the binding and gluing methods

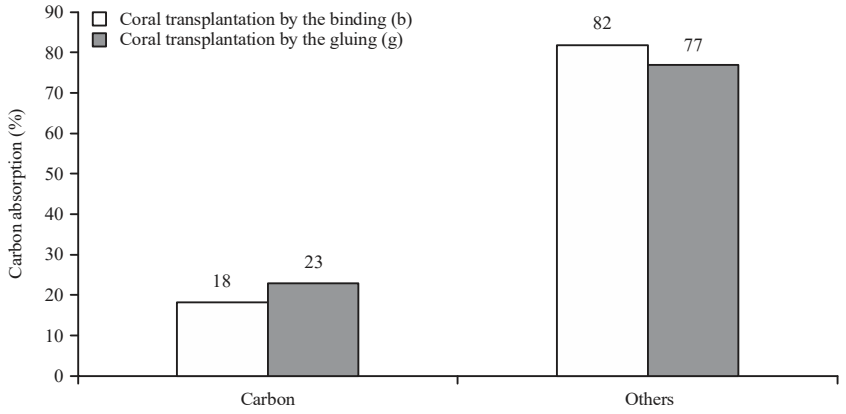

Fig. 5: Carbon absorption (%) of coral transplantation and other by binding and gluing methods

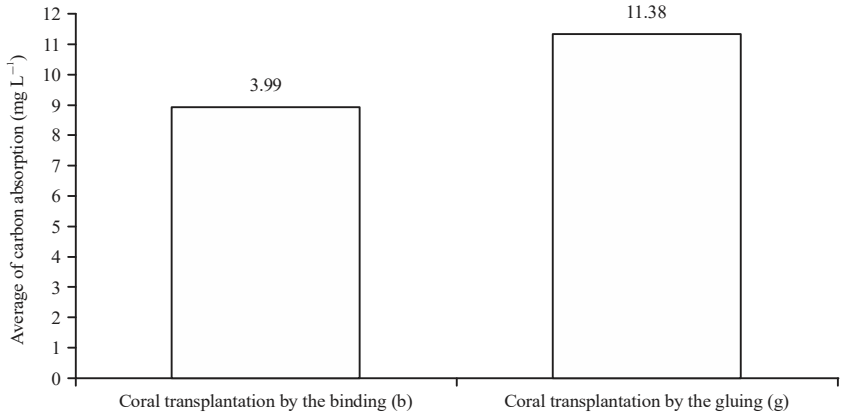

Fig. 6: Average coral absorption of coral transplantation by the binding and gluing methods (mg L^{-1})

Physical and chemical factors of water: The study recorded physical and chemical factors of the water during the field time, which included water temperature (°C), salinity (‰) and pH. Measurements were conducted at the bottom of the water between 3-5 m depth, 5 times a month or once a week during the study. All measurements is presented in Table 3. Water temperature during the study at Taman Nirwana ranged from 30.1-32°C, with salinity ranged from 33-34‰ and pH between 7.6-7. 8.

Table 3: Physical and chemical aspects of water at the study sites

	Month of observation						
Parameters	December	January	February	March	April	May	June
Temperature (°C)	30.1	31.0	31.0	31.8	31.8	31.6	32.0
Salinity (‰)	34.0	33.4	33.0	33.7	33.2	33.2	33.4
pH	7.6	7.6	7.8	7.6	7.6	7.6	7.6

DISCUSSION

The absolute growth rate and the monthly growth of corals transplants with binding method were not different than the ones with gluing method. During the 6 months of observation, both methods tended to develop. Afterward, the transplanted corals with binding method started to decline in its grow rate, whereas the ones with gluing method constantly increase until the end of the observation. It is presumed that the transplanted corals with binding method only grows upward without ability to properly bind the substrate. After the corals sufficiently grow, the transplanted corals will detach from its substrate due to unable to hold the substrate and eventually result in the dying of corals. The PVC pipes, which are actually foreign material for coral along with the binding wire, failed to provide firm foundation for corals. On the other hand, the gluing method used coral glue that promote the growth and attachment of corals to their substrates and will eventually unit as the corals continuously grow. The firm attachment between corals and substrates create an adverse situation for transplanted corals growth rate. According to Zakaria and Nurdin[11], Zakaria *et al.*[13] and Soong and Chen[16] coral transplantation using binding method result in the improper live of corals, in addition to the use of various foreign material which is thought to in adversely affect the coral growth.

The observed addition of coral branches (6±1.14 for binding transplants and 12±0.71 for gluing transplants) were averagely higher than previous study that used several species of *Acropora*[17]. That study transplanted *Acropora formosa* and *A. nobilis* (each with 3 branches), *A. horrida* (5 branches), *A. sarmentosa* (6 branches) and *A. donei* (9 branches). It was assumed that the difference in environmental conditions which later impact the patterns of the coral growth. The coral seedlings used in this study were small in diameter, which may retain potential to produce more branches. Furthermore, the coral seedlings were taken locally from around the study site, which enhance their survival as the stress factor can be tremendously reduced.

Coral's survival rate during transplantation process is counted from the number and percentage of living and nonliving corals. The living transplanted corals at the end of observation period characterized by the color is visible with progressive increment of length and growth of coral. The *Acropora* coral used in this study are brown, brownish green and brownish blue in color. The unsurvived transplanted coral, in addition to be detached from substrate and broken, it had pale or white coloration (bleaching). Died and detached transplanted coral only observed in the binding method, which thought to be caused by the absence of enhancing factor that protect and promote the attachment of coral when planted in the water. In transplanted corals with binding method, the attachment of transplants strengthened whenever the coral branches grew bigger whereas, the transplanted corals with gluing method had better attached to the substrate through the gluing substances, which eventually benefit the grow of corals. The range of survival rates in this study (95-100%) was still categorized as successful rate, as previous study signified that the successful survival range of coral transplantation is in the range[18] of 50-100%.

Based on description analysis, the average carbon absorption in transplanted corals with gluing method was higher than what obtained in transplanted corals with binding method (23%, 11.38 mg L^{-1} compared to 18%, 8.99 mg L^{-1}). The amount of absorbed carbon in transplanted corals with gluing method was in line with its considerable growth rate of length. As carbon uptake by corals is strongly associated with coral growth, the better higher carbon absorption by corals reflect the successful transplantation process. In the binding method, transplanted corals seemed to have more upward growth while they looked or have poor attachment to the substrate that located under the PVC pipes where the corals bound. No firm attachment between transplanted corals and the substrate impact in many things, such as the less optimality to absorb carbon dissolved in the water. As with the gluing method, transplanted corals easily grew attached to the substrate, mostly promoted by the substances contained in the glue, which resembling the coral composition. By this way, transplanted corals have firm binding to the substrate, so eventually maximizing its energy for growing process and sequestrating carbon from the water. All living things allocate their energy for various purpose, namely maintenance, growth and reproduction, in which if a certain living process requires more energy than usual, it will be reduce energy allocated for other processes[19].

According to Timotius[20], carbon absorption is essential for corals as one of its calcification requirements in which affects corals' growth in vertical and horizontal direction. The higher value of carbon absorption in transplanted corals with gluing method compared to ones transplanted with binding method signified that the first method is more suitable to use in coral transplantation as corals can absorb more carbon from surrounding water.

The physical-chemical factors of water such as the temperature during the study recorded between 31-32°C, which slightly higher than various previous studies about coral reefs, that ranged[17,21-23] between 23-31.7°C. Therefore, salinity observed in the water of Taman Nirwana was in accordance with the proper salinity needed to mediate coral transplantation (33-34‰). As it was stated in the previous study that water salinity for optimum successful of coral transplantation should be higher than 32‰ and under[24] 38-40‰. Furthermore, pH measurement showed a constant value 7.6 in each monthly observation, except once in February where it reached 7.8. In overall, the pH of this location resemble the one in previous study that fell between 7-8. The results of pH measurements indicated that there was no problem from pH aspect that may disrupt the growth of transplanted corals[17].

CONCLUSION

The absolute growth rate, the monthly growth rate and the additional of coral branch observed in transplanted corals with binding method were not different with ones treated with gluing method.

The measuring of survival rate and carbon absorption were quantitatively higher in transplanted corals transplantation with gluing method than with binding method.

SIGNIFICANCE STATEMENT

This study proved that the gluing method for coral transplantation has more advantage used for rehabilitating the damaged coral reefs. As the gluing method uses glue with composition similar to the those in natural coral body, enhanced the binding process between transplanted corals with the substrate. This study can help researchers to uncover the critical areas of growth rate and carbon absorption in transplanted corals which previously unexplored. Thus, a novel theory regarding the superiority coral transplantation with gluing method over the binding method should be considered.

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