Mineral Content in Substrate Media, Growth Rate, and Survival Rate of Acropora sp.

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***Abstract*: Coral reef ecosystems are formed from the composition of coral animals that produce lime ($CaCO_3$). Coral animals are animals that do not have a backbone that are included in the phylum Coelenterata. These animals consist of polyps and a skeleton to produce lime. The choice of coral substrate media helps the coral to settle and affects the growth and survival rate of corals. Corals can attach and grow quickly on a suitable substrate medium. This study aims to determine the substrate media's material content, coral growth rate, and the survival rate of *Acropora* sp. transplanted on cement, kanstin faba, and Lapindo brick substrate media. This type of research is experimental. The research design used in this study was a Randomized Complete Block Design. The first group is the difference in substrate media consisting of cement, kanstin faba, and Lapindo brick. The second group is the difference of corals consisting of *A. formosa*, *A. tenuis*, and *A. millepora*. The results showed that the mineral content of the cement substrate media, kanstin faba, and Lapindo brick contained CaO, SiO_2, Fe_2O_3, and Al_2O_3. The highest coral growth rate was found on cement substrate media at 1.63 cm/month, while the highest growth rate based on coral species was in *A. formosa* at 1.63 cm/month. Coral survival rate was highest on cement substrate media and *A. formosa* with a value of 96%.**

***Keywords*: Coral reef, Transplantation, Substrate, *Acropora* sp.**

I. INTRODUCTION

Coral reefs are ecosystems with abundant biodiversity (Romio *et al*., 2017). Many marine biotas live in it both on the seabed and in the water column. Coral reef ecosystems are formed from the composition of coral reef animals that produce lime ($CaCO_3$). Coral animals are animals without backbone that are included in the phylum Coelenterata (Putra *et al*., 2020). These animals consist of polyps and a skeleton to produce lime. The polyp is the soft part, while the skeleton is the hard part (Giyanto *et al*., 2017). But behind the pride of the potential, value, and benefits of the coral reef ecosystem, the quantity (area) and quality of coral reef ecosystems is decreasing year by year (Suparno *et al*., 2018).

The damage of coral reefs continues and increasing. It is predicted that in the 2030s, more than 90% of the world's coral reefs will be threatened by rising temperatures, ocean acidification, and anthropogenic activities by humans (Erika *et al*., 2019). Illegal exploitation of coral reefs for commercial purposes has an impact on the destruction of coral reef ecosystems. This can lead the extinction of coral species and the loss of the ecological function of coral reefs, therefore it is important to restore coral reef ecosystems to suppress and restore the declining condition of coral reef ecosystems. This can be done by transplanting coral reefs.

In transplantation activities, corals that had just been transplanted were injured. Wound closures on newly transplanted corals take 3-4 weeks to heal. Once the wound is closed, coral begins to grow and develop. The choice of coral substrate media helps the coral to settle and affects the growth and survival rate of corals. Corals can attach and grow quickly on a suitable substrate medium. In addition, the coral substrate also influences the calcification and attachment process of coral juveniles. Natural coral substrates contain components such as silica dioxide (SiO_2), calcium oxide (CaO), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), and magnesium oxide (MgO) (Guntur, 2011). The components needed by corals on natural substrates are found in cement, kanstin faba, and Lapindo bricks. Therefore, in this study, the substrate media used were cement, kanstin fly ash and bottom ash (Faba), and Lapindo bricks. The transplant media contains the components that corals need in the substrate for survival rate and growth. This study aims to determine the material content of the substrate media, determine the rate of coral growth, and determine the survival rate of *Acropora* sp. which were transplanted on cement substrate media, kanstin faba, and Lapindo brick.

II. METHODOLOGY

This is an experimental research. The research design used in this study was a Randomized Complete Block Design. In this study there were 2 groups. The first group is the difference in substrate media which consists of 3 types of substrate media, namely cement, kanstin faba, and Lapindo brick. The second group is the different types of corals which consist of 3 types of corals *A. formosa*, *A. tenuis*, and *A. millepora*.

This research was conducted in the Grand Watu Dodol Beach in Ketapang Village, Kalipuro District, Banyuwangi Regency, East Java. The geographical location of this beach is at 8°4'52" East Longitude and 114°25'46" South Latitude. This research was conducted from January to May 2022.

Fig 1. Research map

The tools and materials used in this research are SCUBA diving, underwater camera, GPS, caliper, pliers, cement, kanstin faba, Lapindo brick, and epoxy glue. This study uses three different substrates, namely cement, kanstin faba, and Lapindo brick with three types of *Acropora* sp. those are *A. formosa*, *A. tenuis*, and *A. millepora*. Lapindo brick substrate media used sized of 20 cm x 10 cm x 5 cm, kanstin faba sized of 40 cm x 25 cm x 15 cm, while the use of cement substrate media is circular in shape with a diameter of 5 cm (Khasanah *et al*., 2020). The composition of the substrate media can be seen in Figure 2, 3, and 4.

Fig 2. Arrangement of cement substrate media

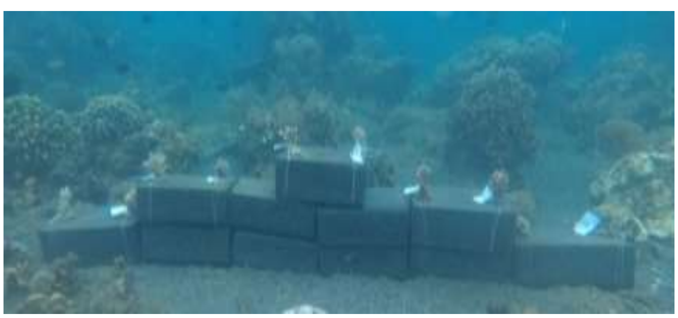

Fig 3. Arrangement of kanstin faba substrate media

Fig 4. Arrangement of Lapindo bricks substrate media

Coral Seed Preparation

Retrieval of coral seedlings is done by looking for corals that have good quality and healthy for transplantation. Selected coral colonies in healthy brooders and do not show symptoms of disease such as natural death or bleaching (Mustafa *et al*., 2020). Retrieval of coral seedlings is done by cutting fragments using pliers or iron scissors with a height of 6 cm.

Adhesive Glue Manufacture

The attachment of coral fragments can be done with cement

and epoxy glue. Making adhesive glue is done by mixing epoxy glue with cement and water. The ratio of the composition of the epoxy glue, cement, and water is 3: 1: 1 (Erika *et al*., 2019). The adhesive glue is used to attach coral fragments to the substrate media.

Fragment Attachment

Adhesive glue is placed in the holes of each substrate sufficiently, then coral fragments are placed on top of the adhesive glue. The method used is the off-bottom method in the process of planting coral fragments on the substrate by attaching coral fragments to the substrate holes which have been filled with adhesive glue.

Coral Transplant Placement

The placement of coral transplants was carried out using the SCUBA diving equipment set. Coral transplants were placed in waters with a depth of ± 4 meters. Treatment of coral fragments is carried out simultaneously with the observation process to prevent coral death.

Data Analysis

Substrate Media Content

The observation of chemical content on substrate media using XRF test. The X-Ray Fluorescence (XRF) method is used to analyze the constituent elements of a material using X-ray radiation that is absorbed and reflected by the target or sample. This method is most widely used for elemental analysis of rock, mineral and sedimentary materials (Fitton, 1997).

Growth Rate

The analysis of coral growth rate was calculated using a caliper and then the data was recorded. To calculate the growth rate of transplanted corals, use the following formula (Ricker, 1975):

$$\alpha = \frac{L\ (i+1) - L(i)}{t(i+1) - t(i)}$$

Description :

α = The rate of increase in length of coral fragment
L(i+1) = Average fragment length at time- i+1
L(i) = Average fragment length at time - i
t(i+1) = At time- i+1
t(i) = At time – i

Survival Rate

The analysis of survival rate of transplanted corals can be calculated using the formula based on (Pratiwi *et al*., 2019) as follows:

$$SR = \frac{Nt}{No} \times 100\%$$

Description :

SR = Coral survival rate (%)
Nt = Number of coral fragments at the end of the study
No = Number of coral fragments at the start of the study

III. RESULTS AND DISCUSSIONS

Result Of Water Quality Measurement

Table 1. Result of water quality measurement

Water Quality Parameters	Observation Time							Average	Std.Dev	Quality Standards
	T0	T1	T2	T3	T4	T5	T6			
Temperature (ºC)	29.28	29.44	30.24	30.57	30.21	29.76	29.92	29.92	0.461	28-30
Brightness (m)	5.32	5.67	6.92	7.28	6.72	6.48	7.64	6.58	0.834	>5
pH	7.73	7.20	7.52	7.33	7.64	8.03	7.74	7.60	0.278	7-8.5
DO (mg/L)	6.85	7.54	7.76	8.21	8.18	7.8	7.93	7.75	0.463	>5
Salinity (ppt)	30.5	31.3	32.5	31.6	30.3	30.8	30.4	31.06	0.798	33-34
Phospate (mg/L)	0.022	0.024	0.021	0.015	0.016	0.019	0.017	0.0191	0.003	0.015
Nitrate (mg/L)	0.017	0.022	0.019	0.021	0.018	0.021	0.022	0.0200	0.002	0.008

*Quality standard According to Decree of Minister of Environment No. 51 of 2004

The growth and survival rate of coral reefs is influenced by internal and external factors. One of the external factors that affect the life of coral reefs is the quality of the waters. The results of the measurement of the water quality of Grand Watu Dodol showed fluctuating results during the study period.

The measurement of water temperature showed an average value of 29.92 ± 0.461ºC. These results were still within the quality standard for coral, according to the Minister of Environment Decree No. 51 of 2004 which has a temperature range of 28-30ºC. The highest temperature observation was found at T3 observations of 30.57ºC while the lowest temperature observations were obtained at 29.28ºC at T0 observations. The temperature obtained in this study fluctuates. The increase and decrease in temperature is caused by changes in weather and differences in measurement time. The optimal temperature range for coral growth is 25-29ºC. The lowest temperature tolerance limit for corals is 16ºC, while the highest is 36ºC (Supriharyono, 2002). A drastic increase or decrease in water quality temperature can inhibit coral growth and metabolism and can even cause coral death.

The measurement of the brightness of the waters showed an average value of 6.58 ± 0.834 m. These results were still within the quality standard of marine biota according to the Decree of the Minister of Environment No. 51 of 2004 which shows a value of >5 m for coral. brightness during the study period showed an increase from the initial measurement time T0 to the time of measurement T3. After that, the brightness decreased at T4 measurement and increased again at T6 measurement. The lowest brightness was obtained at 5.32 m at time T0, while the highest brightness was obtained at time T6 at 7.64 m. The brightness or intensity of light that can enter the waters has an important role in coral life. The brightness level of the waters reaches the range of 7 m including the appropriate category for coral growth and survival rate (Haerul, 2013). The coral's compensation point for light is about 15-20% of the surface intensity. Light penetration rapidly decreases starting from a depth of 10 m (Nybakken, 2000).

The measurement of the pH of the waters showed an average value of 7.60 ± 0.278. These results were still within the quality standard of marine biota according to the Decree of the Minister of Environment No. 51 of 2004 which shows a range of 7-8.5. The lowest pH value was found at T1 measurement time of 7.2 and the highest was 8.03 at T5 time. Suitable habitats for optimal coral growth have a pH value range of 8.2-8.5 (Johan *et al*., 2018). Changes in pH affect the chemical and biological processes of organisms in the waters. pH affects the toxicity of a chemical compound in the waters.

The dissolved oxygen (DO) measurement of the waters showed an average value of 7.75 ± 0.463 mg/L. These results were still within the quality standard of marine biota according to the Decree of the Minister of Environment No. 51 of 2004 which shows a value of > 5 mg/L. An increase of DO occurred at the time of T3 measurement as well as the highest DO value of 8.21 mg/L. The lowest DO value was found in the initial T0 measurement of 6.85 mg/L. A good or optimal DO concentration for coral growth ranges from 6-7 mg/l (Wibawa & Luthfi, 2017). DO content was relatively low along the bottom of the water, probably due to the respiration process by corals and other reef-building biotas in the bottom of the water.

The measurement of water salinity showed an average value of 31.06 ± 0.798 ppt. These results were still within the quality standard for coral according to the Decree of the Minister of Environment No. 51 of 2004 has a salinity range of 33-34 ppt. The highest salinity level at the time of T2 measurement was 32.5 ppt while the lowest was 30.3 ppt at the time of T4 measurement. Decrease of salinity levels at T4 because at that time there was an increase in the intensity of rain so it affected the decrease in salinity. Coral stress pressure on the effect of salinity did not show a significant change but the effect of salinity could cause certain coral species to tolerate changes in water salinity. Generally, coral reefs grow well in near-coastal areas at 30–35 ppt salinity (Oktarina *et al*., 2014).

Water phosphate measurements showed an average value of 0.0200 ± 0.0020 mg/L. These results were still within the quality standard of marine biota according to the Decree of the Minister of Environment No. 51 of 2004 which showed a value of 0.015 mg/L. The value of high phosphate levels in waters is influenced by the seasons. High phosphate values at T1 and T6 were influenced by the rainy season. Phosphate contamination can affect coral organisms, altering growth rates, coral reproduction, coral mortality, and zooxanthellae density (Dunn *et al*., 2012). The concentration of phosphate and nitrate content in water greatly determines the high and low density of zooxanthellae found in coral colonies of *Acropora* sp. The range of good phosphate concentrations for coral growth and health is 0.07 mg/l (Mellani *et al*., 2019).

The measurement of water nitrate showed an average value of 0.0191 ± 0.0033 mg/L. These results were still within the quality standard of marine biota according to the Decree of the Minister of Environment No. 51 of 2004 which shows a value of 0.008 mg/L. The high value of nitrate obtained at the time of the study did not affect the decline or mortality of the transplanted coral reefs because coral reefs were able to tolerate high nitrate values at the study site. Nitrate is one of the important nutrient compounds in protein synthesis of aquatic biota, including corals. The high concentration of nitrate and phosphate in waters causes stress on corals which results in lower coral cover and higher diversity of diseases and prevalence of coral diseases. The range of nitrate concentrations that are good for coral health is 0.040 mg/L (Dedi *et al*., 2016).

Composition of Mineral Content of Transplant Substrate Media

Artificial reefs as artificial habitats allow to stimulate coral growth and provide habitat for fish and other aquatic organisms. calcareous algae, sponges, juvenile reef fish, and other organisms have been found in and around artificial reefs (Ilyas *et al*. 2003). The natural substrate of coral reefs contains several chemical elements such as silica dioxide (SiO_2), calcium oxide (CaO), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), and magnesium oxide (MgO) (Guntur, 2011). The substrate medium used in transplanting *Acropora* sp. includes cement, kanstin faba, and Lapindo brick. Each substrate media contains different compositions.

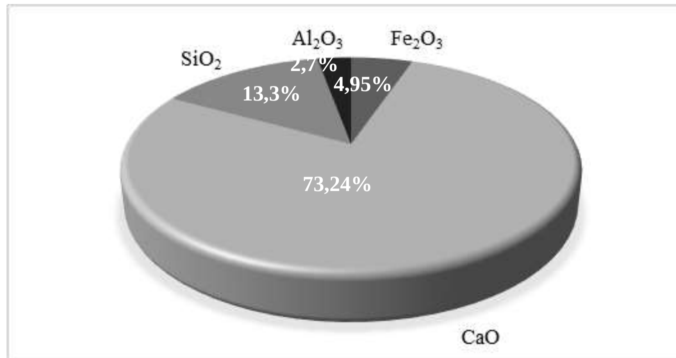

Fig 5. Mineral content in cement substrate media

Based on the XRF test analysis, the material content in the cement substrate media obtained the highest content, namely CaO of 73.24%, while the lowest content was Al_2O_3 of 2.7%. The main compounds in the composition of cement are lime oxide ($CaCO_3$), silica oxide (SiO_2), alumina oxide (Al_2O_3), and iron oxide (Fe_2O_3) (Marzuki, 2009). The high CaO content in cement substrate media affects the growth of *Acropora* sp. in survival rate. Calcium carbonate ($CaCO_3$) is the main constituent of the coral skeleton so high calcium content can support the rate of coral growth. Coral reef ecosystems are formed from the composition of coral reef animals that produce lime ($CaCO_3$). These animals consist of polyps and a skeleton to produce lime.

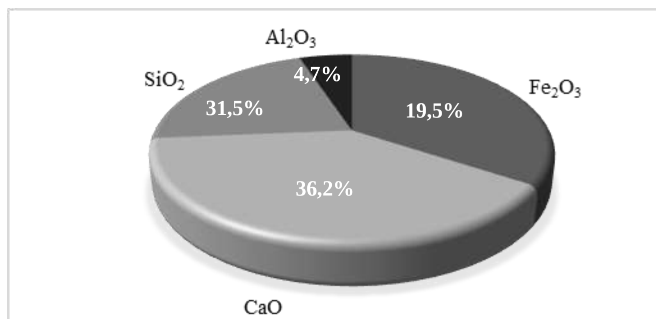

Fig 6. Mineral content in kanstin faba substrate media

Based on the XRF test analysis, the material content of the fly ash and bottom ash kanstine substrate media obtained the highest content, namely CaO of 36.2%, while the lowest content was Al_2O_3 of 4.7%. Based on Government Regulation Number 22 of 2021 concerning Implementation of Environmental Protection and Management, fly ash and bottom ash waste are no longer classified as B3 waste. After the TCLP (Toxicity Characteristic Leachate Procedure) test was carried out by the ALS Indonesia Lab which stated that this product had no potential to pollute the environment. Fly ash and bottom ash contain minerals such as magnesium (Mg), calcium (Ca), potassium (K), ferrum/iron (Fe) and silicate (SiO_2) which are needed by coral planula larvae to settle in juvenile coral form. These contents influence and contribute to the needs of life and coral growth (Khasanah *et al*., 2020).

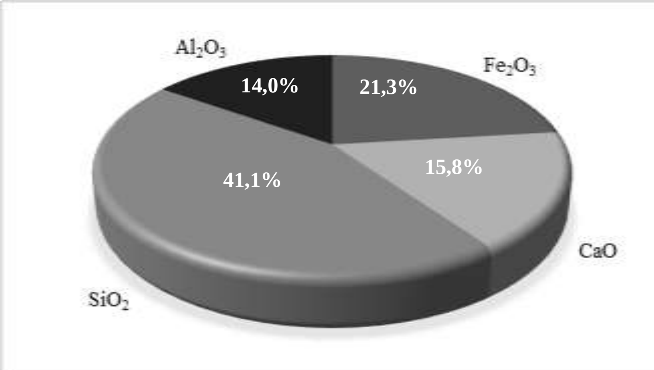

Fig 7. Mineral content in kanstin faba substrate media

Based on the XRF test analysis of the material content in the Lapindo brick substrate media, the highest content was obtained, namely SiO_2 of 41.1%, while the lowest content was Al_2O_3 of 14.0%. Lapindo mud contains elements of SiO_2, CaO, Al_2O_3, Fe_2O_3, TiO_2, MgO, Na_2O, K_2O, and SO_2. The elements contained in the Lapindo mud can be used as a building material as a substitute for cement, ceramics, tile, coal, and brick (Listiyani *et al*., 2019). Based on toxicological testing, it was found that Lapindo mud is not included in B3 waste (hazardous and toxic materials), so Lapindo mud can be used as a building material and is safe for health (Suprianto, 2012). The content contained in the Lapindo mud is the content needed by corals to meet the needs of life and in the growth process.

Growth Rate

The measurement of coral growth rate was carried out by direct observation using SCUBA diving equipment. The results showed that there were differences in growth rates between each type of transplanted coral and the type of substrate used. Coral growth begins with wound closure due to cutting coral fragments. Closure of coral wounds takes about 2-4 weeks after cutting the fragments at the time of transplant depending on the condition of each type of coral.

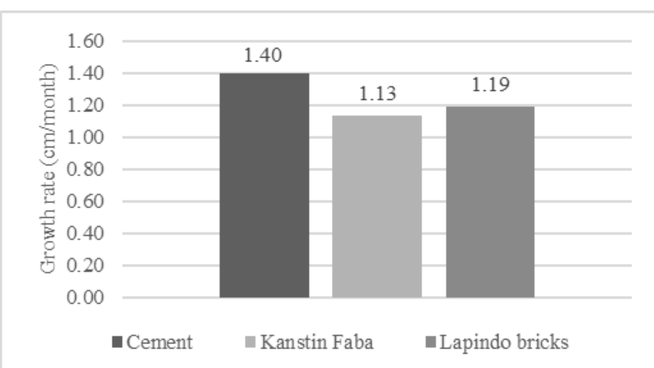

Fig 8. Growth rate according to substrate media

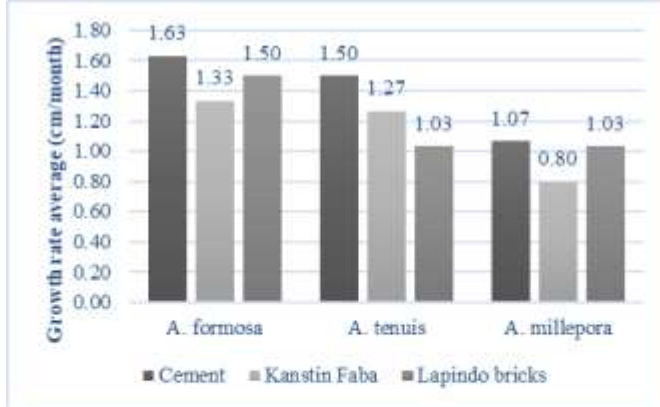

Fig 9. Growth rate according to type of coral and substrate media

Based on the results of measurements of coral growth rate, it showed that the highest growth rate of coral was on cement substrate media at 1.40 cm/month, while the lowest growth rate was on kanstin faba substrate media at 1.13 cm/month. Differences in growth rates are influenced by various factors, both internally and externally. According to Soong and Chen (2003), said that the larger fragment size has a faster growth rate. The larger the fragment size, the higher the number of polyps the higher the number of zooxanthellae so that they can utilize food optimally and the growth rate will be faster.

Different types of transplanted corals also affect the rate of coral growth. Type *A. formosa* has the highest growth rate on cement substrates at 1.63 cm/month, while *A. tenuis* has the highest growth rate on cement substrate media at 1.50 cm/month, and *A. millepora* the highest on cement substrate media at 1.07 cm/month. Environmental factors also support the rate of coral growth, one of which is light. The speed of coral growth is influenced by the phototoric nature of corals, in other words the process of coral growth is influenced by light. This is related to the photosynthesis process carried out by the zooxanthellae symbiont algae for the calcification process. The more zooxanthellae in coral tissue will increase the photosynthetic ability so that the rate of structural calcification for growth becomes faster (Zulfikar and Soedharma, 2008).

Survival Rate

To measure the success of a coral transplant can be seen through the survival rate of corals (Partini, 2009). The results of survival rate observations based on substrate media and coral species can be seen in Figures 10 and 11.

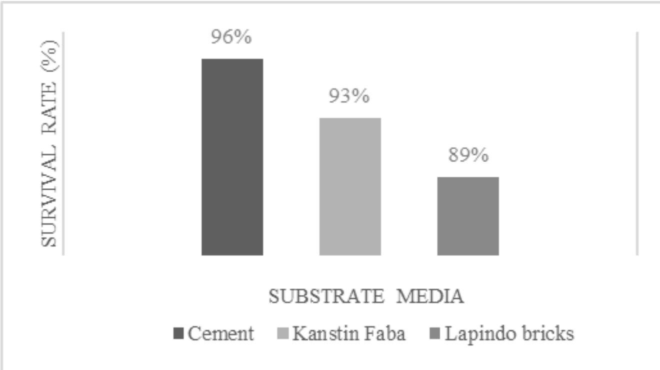

Fig 10. Survival rate according to substrate media

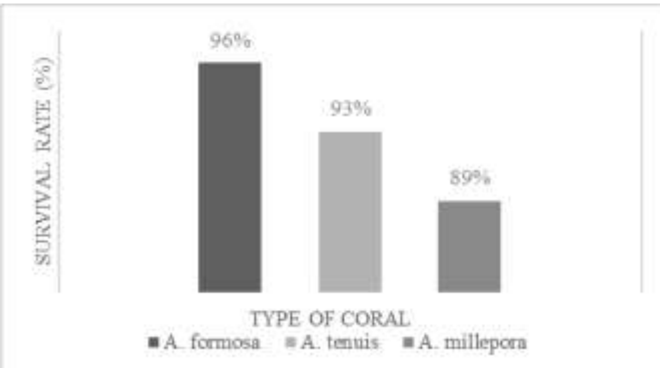

Fig 11. Survival rate according to type of coral

Based on observations, it can be seen that the highest survival rate rate is on cement substrate media with a value of 96%, then kanstin faba media is 93%, and last Lapindo brick media is 89%. Based on coral species, the highest survival rate rates were *A. formosa* at 96%, *A. tenuis* 93%, and *A. millepora* at 89%. The growth and survival rate of coral reefs is influenced by oceanographic factors such as physics, chemistry, and biology. In addition, another influencing factor is the stress level of corals. Coral stress levels are influenced by environmental factors and the size of coral fragments. Fragment size that is too small causes fewer associated zooxanthellae and coral fragments are more susceptible to death.

IV. CONCLUSION

The best substrate media in this study was obtained on cement media containing CaO 73.24%, SiO_2 13.3%, Fe_2O_3 4.95%, and Al_2O_3 2.7%. The highest growth rate of coral was found on a cement substrate media of 1.40 cm/month. While the highest growth rate of *Acropora* sp. was in *A. formosa* at 1.63 cm/month. The highest coral survival rate was on cement substrate media and *A. formosa* with a value of 96%.

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