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Influence of Perifiton Substrate Density on Growth, Survival Rate, and Biomass Gain of Vannamei Shrimp (*Litopenaeus vannamei*) in Ponds

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Abstract

This study aims to determine the effect of periphyton substrate density on growth, survival rate, and biomass gain of vannamei shrimp (*Litopenaeus vannamei*) in ponds. This study was conducted from February 1, to March 31, 2023 at the traditional ponds in Lawallu Village, Soppeng Riaja Subdistrict, Barru Regency, South Sulawesi Province. The test animal used were vannamei shrimp seeds (PL 17–20) stocked at a density of 50 individual/m^2. Completely randomized design was used, with 4 treatments and 3 replications for each treatment. The parameters observed were weight and length gain, survival rate, and biomass gain. At the end of rearing, the average weight gain in each treatment were A (3.4 g), B (3.8 g), C (4.1 g), and D (4.7 g); the average length gain in each treatment were A (3.2 cm), B (5.4 cm), C (5.97 cm), and D (6.97 cm); the average survival rate in each treatment were A (83%), B (89%), C (90%), and D (94%); and the average biomass gain in each treatment were A (287 g/m^2), B (335 g/m^2), C (372 g/m^2), and D (443 g/m^2). Periphyton substrate density has significantly affected the growth and biomass gain of vannamei shrimp seeds. The highest growth, survival rate, and biomass gain were obtained at treatment D, namely using periphyton substrate at a density of 15 bamboos/m^2.

Keywords: Periphyton, Ponds, Substrate density, Vannamei shrimp (*Litopenaeus vannamei*).

1. Introduction

Vannamei shrimp (*Litopenaeus vannamei*) is one of the leading products of the fisheries sector. Various advantages possessed, namely the ease of cultivating this shrimp as well as stable production and relatively resistant to disease cause the majority of fishery farmers in Indonesia to cultivate vannamei shrimp (Kaligis, 2015). In addition, according to Bray et al. (1994), there are other advantages of vannamei shrimps, namely they are eurihaline, meaning that these shrimps are able to live in waters at the wide range of salinities, namely from 0.5–40 ppt.

Vannamei shrimp is one of the fishery products that can generate foreign exchange for the country. For the period of 2020–2024, Ministry of Marine and Fisheries targeted shrimp export value at US$4.25 billion or 250% growth, while production was targeted at 2 million tons. Shrimp export volume in 2022 was recorded at 240,000 tons, declined from 250,700 tons in 2021. Similarly, the export value of shrimp in 2022 was US$2.16 billion, declined from US$2.23 billion in the previous year (Kompas, 2023).

Vannamei shrimp farming is growing rapidly with intensive technology due to the availability of SPF (Specific Pathogen Free) seeds, which can be stocked at higher densities, and thereby can generate high survival and production (Poernomo, 2004). In Indonesia, densities commonly practised in various regions range from 80 to 100 individual/m^2 of vannamei shrimp and can be increased to 244 individual/m^2 using probiotics that can produce 37.5 tons/ha/cycle (Poernomo, 2004).

High density seed stocking will increase shrimp competition to obtain food, space, living space, and oxygen. This causes the survival rate of shrimp to decrease because shrimps naturally exhibit cannibalism trait, namely they like to prey on fellow species (Hidayat et al., 2013). Cannibalism in shrimps can occur when they experience stress condition or the rations is given less than the normal dose. Thus, additional feeding is needed, one of which is by providing natural rations. By providing natural rations, the sufficient availability of rations in the waters can be fulfilled (Rakhfid et al., 2017b; 2017a). The accelerated growth of vannamei shrimp in ponds is influenced by several factors. Environmental conditions, such as tillage and fertilization, can enrich waters with additional nutrients, which also function to grow and multiply the amount of natural rations (Rakhfid & Mauga, 2018).

One of the good natural rations for the growth of vannamei shrimp is periphyton. The application of periphyton can fulfil the protein needs of vannemei shrimp seeds for support their growth (Pratiwi et al., 2007). The use of periphyton can also reduce rations costs by up to 60% (Irianto et al., 2011). Periphyton are all microorganisms, including microscopic algae, bacteria, and fungi, that live on a substrate submerged in water (Sigee, 2005). Periphyton growth requires a substrate, especially a natural substrate for attachment on the medium (Azim et al., 2002). Periphyton production per unit area can be up to three times that of phytoplankton and ten times that of microfauna. Substrate type largely determines the colonization process and composition of periphyton, which is closely related to its attachment ability and tools (Pratiwi et al., 2007). In addition, Harlin (1980) stated that the types of periphyton found on natural substrates are more numerous than those found on artificial substrates. Periphyton on natural substrates will cause environmental changes as a result of their respiration and assimilation.

Azim et al. (2002) stated that 29–64% of the organic matter that makes up periphyton on bamboo substrate is microalgae, while the rest consists of heterotrophic organisms, such as heterotrophic bacteria, fungi, yeast, protozoa, and micro-metazoa. The introduction of hard-surfaced objects, such as bamboo sticks and paralon into the pond, is intended as a substrate for the growth of periphyton, which will serve as natural rations for the fish or other aquatic organisms. This system is commonly referred to as periphyton-based ponds.

Periphyton-based ponds have been traditionally applied by fish farmers in Africa, as stated by many previous studies (Hem & Avit, 1994; Wahab & Kibria, 1994; Beveridge et al., 1998; Wahab et al., 1999; Azim et al., 2001; Keshavanath et al., 2001; Milstein et al., 2005; Campu et al., 2020) as a way to increase fishery yields. The experiment of Uddin et al. (2007) using tilapia and shrimp cultured in periphyton ponds with bamboo substrate revealed that tilapia and shrimp in bamboo ponds had higher survival rates (60 and 35%, respectively) compared to that of in ponds without bamboo (55 and 20%, respectively).

Based on the aforementioned background, bamboo was chosen as the artificial substrate in this study because it is relatively durable in water and easily available at affordable prices. Therefore, this study aims to determine the effect of periphyton substrate density on growth, survival rate, and biomass gain of vannamei shrimp (*Litopenaeus vannamei*) in ponds.

2. Methods

2.1 Time and Location

This study was conducted from February 1, to March 31, 2023 at the traditional ponds in Lawallu Village, Soppeng Riaja Subdistrict, Barru Regency, South Sulawesi Province.

2.2 Tested Animal

The test animals used in this study were vannamei shrimp seeds (PL 17–20) stocked at a density of 100 individual/m^2, namely one-third of the typical intensive system stocking density of 60–150 individual/m^2 (Briggs et al., 2004).

2.3 Research Design

This study applied completely randomized design (CRD) with 4 treatments and 3 replication for each treatment. The description of each treatment used is presented as follows (Cesar et al., 2012). The rearing was conducted in all treatments for four weeks.

Treatment A = Control (without periphyton substrate)
Treatment B = Periphyton substrate density of 5 bamboos/m^2
Treatment C = Periphyton substrate density of 10 bamboos/m^2
Treatment D = Periphyton substrate density of 15 bamboos/m^2

2.4 Preparation of Rearing Containers

The rearing container used was the cages made of green nets and bamboo substrate in the nets, measuring the size of 1 meter long, 1 meter wide, and 1 meter high. There were 12 units of containers used in this study. First, the net was formed into a square or commonly known as a hapa. The hapa that has been formed was immediately placed in a pond filled with water. All sides of the square-shaped net were fitted with bamboo pieces as anchors. All bamboos used were 150 cm long. The bamboo was placed and planted in the net as a substrate for periphyton to attach. The bamboo was firmly fixed so that it would not collapse during the rearing. Once the research container was ready for use, the seeds of vannamei shrimp were inserted into the hapa. The seeds were then fed with rations as many as 5 g/plot in the morning and evening.

Figure 1. Rearing containers

2.6 Research Parameter

Weight and length gain

Weight and length gain of vannamei shrimp were determined using the equations according to Effendie (1979) as follows.

$$\text{Absolute weight gain} = Wt - Wo$$

Description:
Wt : Final weight (g)
Wo : Initial weight (g)

$$\text{Absolute length gain} = Lt - Lo$$

Description:
Lt : Final length (cm)
Lo : Initial length (cm)

Survival rate

Survival rate of vannmei shrimp seeds was determined using an equation according to Effendie (1979) as follows:

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

Description:

SR : Survival rate (%)
Nt : Number of vannamei shrimp that alive at the end of rearing (individual)
No : Number of vannamei shrimp that alive at the beginning of rearing (individual)

Biomass Gain

Biomass gain was determined by the following equation (Sikong, 1982).
Biomass gain = Final biomass (g/m^2) – initial biomass (g/m^2)

2.7 Data Analysis

The data obtained in this study were displayed in the form of graphs and tabulations. To see the effect of treatment, the data were analyzed using analysis of variance (ANOVA) and Tukey's further test to determine the differences among treatments. The tool used was SPSS version 21.0 for Windows (Santoso, 2010). For graphical presentation and data tabulation, Microsoft Excel 2007 was used (Madcoms, 2015).

3. Results and Discussion

3.1 Weight Gain

The average weight gain of vannamei shrimp in each treatment during rearing is displayed in Figure 2.

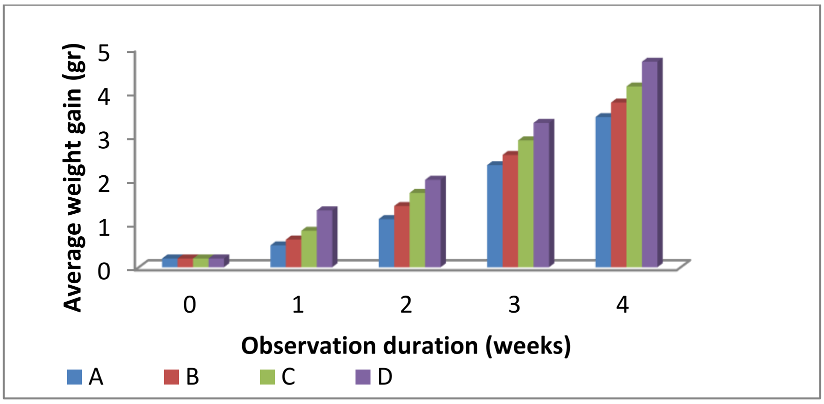

Figure 2. Average weight gain of vannamei shrimp during rearing

By the end of rearing (fourth week), the weight gain obtained by treatment D, namely from using periphyton substrate at a density of 15 bamboos/m^2, is the highest of all other treatments. The average weight gain in each treatment were A (3.4 g), B (3.8 g), C (4.1 g), and D (4.7 g). This is in accordance with a study by Campu et al. (2020). The results of analysis of variance show that the density of periphyton substrate during rearing had a significant effect at $P < 0.05$ or Sig = 0.00 on the weight gain of vanamei shrimp seeds.

Growth is commonly indicated by an increase in weight or length in a certain period of time (Effendie, 1979). Figure 2 shows that little variation began to appear in the first week. This is thought to be due to the use of energy from shrimp seeds that is still small, especially in the formation of somatic cells so that weight gain tends to be uniform.

From the second week until the end of rearing, the presence of periphyton affected the weight and length gain of vannamei shrimp seeds. Periphyton can fulfil the protein needs of vannamei shrimp seeds for growth (Pratiwi et al., 2007). The use of periphyton also can reduce rations costs by up to 60% (Irianto et al., 2011).

Shrimp growth, in addition to being influenced by artificial rations, is also influenced by the availability of natural rations in the form of periphyton because the rations provided meets the protein needs of shrimp. In addition, stocking density also affects shrimp growth. This is consistent with the statement that an increase in stocking density will reduce growth of aquatic organism (Purnama, 2003).

The result also shows that the seeds growth occurred at a rate of 1 to 2.5 g/week. This is in accordance with a study by Supono (2006), which stated that vannamei shrimp seeds can grow well at a growth rate of 1–1.5 g/week.

3.2 Length Gain

The average length gain of vannamei shrimp in each treatment during rearing is displayed in Figure 3.

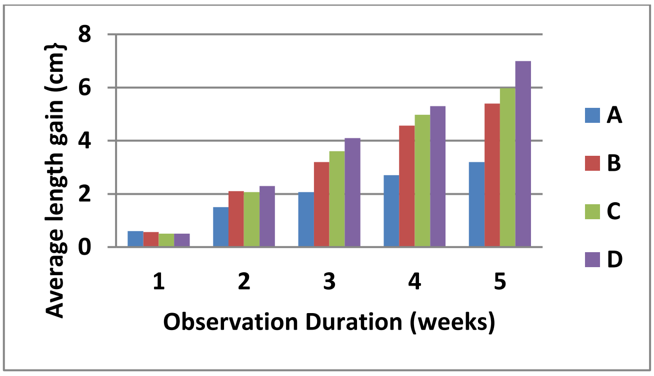

Figure 3. Average length gain of vannamei shrimp during rearing

It can be seen from Figure 3 that at the beginning of rearing (first week), all treatments produced the relatively same increase of shrimp length. The increase in length began to show differences in the second week until the end of rearing. The length gain (total body length from rostrum to tail) obtained in each treatment were A (3.2 cm), B (5.4 cm), C (5.97 cm), and D (6.97 cm). The results of analysis of variance show that the density of periphyton substrate during rearing had a significant effect at $P < 0.05$ or Sig = 0.034 on the length gain of vannamei shrimp seeds.

3.3 Survival Rate

Survival rate is the ratio between the number of individuals at the end of the experiment and the number of individuals at the beginning of the experiment. Biotic factors that affect the survival rate include parasites, competitors, predators, age, adaptability, human handling, and population density. Meanwhile, abiotic factors that affect survival are physical and chemical factors of a given environment (Rika, 2008).

The average survival rate of vannamei shrimp in each treatment during rearing is presented in Figure 4.

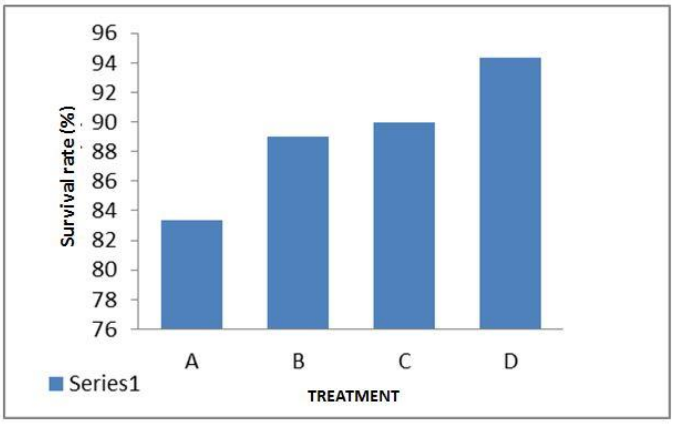

Figure 4. Average survival rate of vannamei shrimp during rearing

The results of analysis of variance show that the density of periphyton substrate during rearing had no significant effect at P > 0.05 or P > 0.1 on the survival rate of vannamei shrimp seeds.

However, Figure 3 shows that the highest survival rate was obtained in treatment D (94%). This result is in accordance with a study by Campu et al. (2020). The result of treatment D is thought to be due to the sufficient availability of periphyton in the substrate. Meanwhile, the lowest survival rate was obtained in treatment A (83%). This is due to the absence of a substrate used as a medium for the growth of periphyton as the natural rations for vannamei shrimp seeds in addition to artificial rations. The decrease in survival rate was due to the narrow container, thus resulting in competition for obtaining the rations. As a comparison, Tahe (2008) produced the highest shrimp survival rate of 93.33% through the feeding frequency of 4 times/day, followed by that of 3 times/day (93.33%), and twice/day (91.335%).

3.4 Biomass Gain

The average biomass gain of vannamei shrimp in each treatment during rearing is displayed in Figure 5.

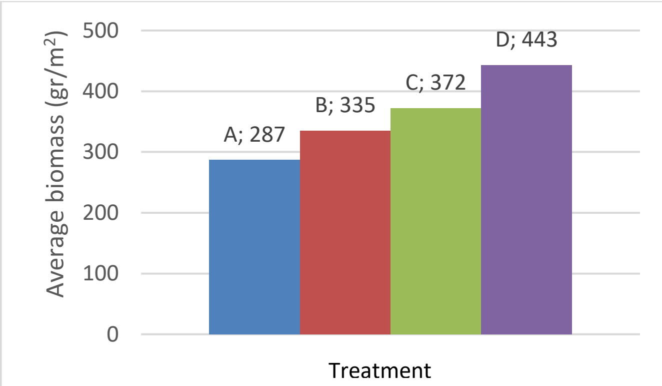

Figure 5. Average biomass gain of vannamei shrimp during rearing

The average biomass gain of vannamei shrimp in each treatment were A (287 g/m^2), B (335 g/m^2), C (372 g/m^2), and D (443 g/m^2). Soegianto (2004) stated that the biomass gain can be determined by measuring either dry weight or wet weight obtained. The results of the analysis of variance show that the density of periphyton substrate during rearing had a significant effect at P < 0.05 or Sig = 0.030 on the biomass gain of vannamei shrimp seeds.

3.5 Water Quality Parameter

Water quality is any variable in the aquatic environment, whether physical, chemical, or biological, that affects the survival, growth, and biomass of aquatic organisms (Boyd, 1982). The results of water quality parameter measurement in each treatment during rearing are shown in Table 1.

Table 1. Results of Water Quality Measurement during Rearing.

Parameter	Treatment			
	A	B	C	D
Temperature (°C)	28–32	28–32	28–32	28–32
Salinity (ppt)	15–25	15–25	15–25	15–25
pH	7.0–8.5	7.0–8.5	7.0–8.5	7.0–8.5
DO (ppm)	5.0–6.0	5.0–6.0	5.0–6.0	5.0–6.0
Brightness (cm)	20–25	20–25	20–25	20–25

Optimal water temperature indicates a warm zone that gets sufficient solar radiation during the day, as it can optimally facilitate aquatic metabolism and oxygen solubility. The temperature obtained during rearing ranged from 28–32°C. This is in accordance with Zakaria (2010), which stated that the optimal temperature for shrimp growth ranges from 26–32°C.

The dissolve oxygen (DO) concentration obtained during rearing ranged from 5.0–6.0 ppm. Shrimps require sufficient DO concentration for sustaining their life, reproduction, and growth. Low DO concentrations cause shrimps to lost appetite towards their rations so that this can inhibit their growth rate. If it lasts for any longer, they will stop eating, experience stress, and eventually die.

Acidity level (pH) is a measure of the concentration of hydrogen ions and indicates whether the state of water is acidic or alkaline. pH level obtained during rearing ranged from 7.0–8.5. According to Ferreira et al. (2011), shrimp cultivated in the sea can grow optimally in the pH range of 6–9.

Salinity level obtained during rearing ranged from 15–25 ppt. This range is considered very feasible to support the life of shrimp and fish living in the waters. Low salt concentration can cause shrimp to float on the water surface, and if it lasts for any longer, it will cause death in shrimp (Alava, 2011).

The amount of light entering the water is expressed as degree of brightness (cm). The level of brightness obtained during rearing ranged from 20–25 cm. The high level of brightness can increase the growth of periphyton because photosynthetic occurs more maximally and is still in the range that supports the growth of shrimp. According to Arie (2003), the optimal brightness to support the growth of aquatic organisms ranges from 20–40 cm.

4. Conclusion

From the results of this study, the following conclusions can be drawn. The density of periphyton substrate has significantly affected the growth and biomass gain of vannamei shrimp seeds. The highest growth, survival rate, and biomass gain were obtained at treatment D, namely using a periphyton substrate at the density of 15 bamboos/m^2. The higher the substrate density, the better the growth, survival rate, and biomass gain obtained. Based on these results, it is recommended to conduct further studies by increasing the amount of bamboo substrate as a medium for periphyton growth so as to generate the optimal results in the production yield of vannamei shrimp.

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