The nursery of *Litopenaeus vannamei* at different density using aeration system on pond

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Abstract. The nursery of shrimp is an intermediate effort to connect hatchery and grow-out process, wherein shrimp fry was rear in a controlled process in a certain time before reared on pond. The study was aimed to evaluate the growth and survival rate of white shrimp (*L. vannamei*) under different stocking density in nursery phase on pond. The nursery of *L. vannamei* was carried out at experimental pond installation of Research Institute for Coastal Aquaculture and Fisheries Extension (RICAFE) in Maros-South Sulawesi using a 5.5 x 11 m² size of ponds, which was equipped with a bottom aeration system. The water depth of pond was 40 cm. Pond preparation was done by pond repairing, maintaining, drying, and eradicating using 20 ppm of saponin, flushing and water filling gradually until maximum of water level. The fry of *L. vannamei* (PL-10) with an average initial weight of 0.002 g, which obtained from hatchery, were stocked. The treatments were stocking density of *L. vannamei* fry namely 1,653 individuals/m³ or 40,000 individuals/pond (A) and 909 individuals/m³ or 22,000 individuals/pond (B). Commercial powdered feed was given 3 times/day in 50–100% of biomass weight calculation base. The parameters observed were growth rate, survival rate of white shrimp and water quality condition. The results showed water quality variables including temperature, dissolved oxygen, pH, salinity, and alkalinity were in a suitable range for growth and survival of *L. vannamei*. The survival rate of *L. vannamei* in 21 days nursery was 86.40-95.61% and the final weight ranging from 0.292 to 0.320 g/ind.

1. Introduction
Shrimp farming vaname (*Litopenaeus vannamei*) involves three stages of activity: seeding, nursery, and grow-out. Seeding activities include maintaining shrimp broodstock to produce seeds post larva size (PL) ranging from PL-5 to PL-12 and the production of nauplius for further maintenance in the backyard or seeding household scale. While the nursery activity is ongoing, a follow-up seeding activity is necessary to collect seeds ranging in size from PL-5 or PL12 to juvenile (size ready to spread in the pond). In comparison, the grow-out activity is responsible for maintaining the shrimp vaname from juvenile to consumption or marketable size. The nursery phase is a transition period between larval rearing and shrimp grow-out. It is typically conducted in tanks with a higher stocking density than those used during the grow-out phase. This procedure enables improved management control and biosecurity during the early stages of cultivation, which benefits the animals' zootechnical performance during the grow-out phase and benefits related to culture area and yield optimization [1], [2].

The nursery management team strives for a higher survival rate and a healthier condition of shrimp for stocking in the grow-out pond. This is possible due to the pond's relatively small size,
which allows for more controlled rearing and maintenance, such as water quality monitoring, eradication of wild fish, or addition of commercial feed [3]. The advantage of the nursery phase is that it increases the vitality of the PL, which results in increased pond productivity, efficiency in the use of feed, suitability of spread patterns in grow-out, and shortens maintenance time in the enlargement pond, which reduces the risk of disease, in addition to providing accurate seed distribution calculations in the enlargement pond [4], [5].

Nurseries are a critical component of aquaculture systems, as they serve as a transitional phase between the initial post-larval stage and the grow-out phase [6], [7]. Between the hatchery and grow-out phases, a nursery phase for shrimp can optimize space utilization, improve biosecurity, and produce hardier juveniles for stock production systems. The nursery phase is a strategy for obtaining shrimp uniform in size, have a higher survival rate, and are more tolerant of environmental variations, resulting in increased biosafety in aquaculture systems, as nurseries serve as quarantine units for monitoring potential diseases [8].

Container design and maintenance methods affect the environmental condition of the maintenance media, the accuracy with which biota needs are met, and ultimately on the quality and quantity of seed [9]. Shrimp production technology has been widely applied in various ways, including shrimp nursery production in ponds and the use of happa in ponds equipped with paddlewheels and blowers. Shrimp nursery in a floating net cage in the sea, nursery with a permanent/concrete pond, and fiberglass [10], [11], [12], [13]. The nursery phase’s quality of postlarvae management is critical for their growth and survival, as well as the foundation for juveniles’ maximum growth performance during the grow-out phase.

The purpose of this study was to determine the effect of stocking density on the growth and survival rate of Litopenaeus vannamei during the nursery phase using an aeration system in a pond.

2. Materials and method

2.1. Location
The research was carried out at Research Institute for Coastal Aquaculture and Fisheries Extension (RICAFE), Maros, South Sulawesi, Indonesia.

2.2. Pond preparation and treatment experimental
The nursery containers used 5.5 x 11 m² size of pond which was equipped with a bottom aeration system. The water depth of pond was 40 cm. Pond preparation was done by pond repairing, maintaining, drying, eradicating using 20 ppm of saponin, flushing and water filling gradually until maximum of water level. The fry of L. vannamei (PL-10) with an average initial weight of 0.002 g which obtained from hatchery were stocked. The treatments were stocking density of L. vannamei fry namely 1,653 individuals/m³ or 40,000 individuals/pond (A) and 909 individuals/m³ or 22,000 individuals/pond (B). Commercial powdered feed was given 3 times/ day in 50–100% of biomass weight calculation base. The parameters observed were growth rate, survival rate of white shrimp and water quality condition.

2.3. Observed variables
The variables observed were the weight growth of the white shrimp including initial weight, final weight, absolute weight and daily growth rate. The weight was measured using an electric scale with an accuracy of 0.01 g. The number of samples of white shrimp was 50 shrimps that were carried out every week. The survival rate of the white shrimp was observed at the end of the study. The observations of water quality variables (temperature and dissolved oxygen (DO meter), salinity (hand refractometer), pH (pH meter), and alkalinity (titration method with sulfuric acid), were measured every week,
2.4. Data analysis

The data on the growth, survival rate of the white shrimp and water quality obtained was tabulated and analyzed descriptively.

3. Result and discussion

3.1. The growth of white shrimp

The observations of the growth and survival rate of white shrimp during the nursery phase with aeration system are presented in Table 1 below.

**Table 1. Performance of growth (g) and survival rate (%) of white shrimp (L.vannamei) for 21 days of rearing period**

| Variable                        | Stocking density       |
|---------------------------------|------------------------|
|                                 | 1,653 ind/m³ (A)       |
|                                 | 909 ind/m³ (B)         |
| Containers volume (m³)          | 24.2                   |
| Rearing period (day)            | 21                     |
| Initial weight (g/ind)          | 0.002±0.00             |
| Final weight (g/ind)            | 0.292±0.05             |
| Absolute weight (g/ind)         | 0.290±0.05             |
| Specific Growth Rate (%/day)    | 23.67±0.95             |
| Number of initial seeds (ind/pond) | 40,000±0.00       |
| Number of seeds harvested (ind/pond) | 34,560±4226       |
| Survival rate (%)               | 86.40±10.56            |

Based on table 1, the average weight gain of white shrimp in each plot is approximately 0.292-0.320 g/ind, with a specific growth rate of 23.67-24.16 %/day. The white shrimp nursery phase has a high growth value. The average weight of nursery white shrimp obtained during maintenance was 0.14–0.77 g/ind. Seed maintenance in ponds using happa containers yielded seed weights ranging from 0.11–0.61 g/ind, followed by rearing on caramba floating nets (KJA), yielding seed weights ranging from 0.12–0.50 g/ind, while the nursery using pond containers yielded seed weights ranging from 0.54-0.65 g/ind [13]. The weight of white shrimp obtained from various feed combinations at the nursery stage and maintained for 21 days ranged between 0.027-0.047 g/ind [14]. The average final weight of white shrimp maintained in biofloc systems with varying C/N ratios ranges between 0.59 and 1.26 g, with white shrimp growing at a rate of 15.79-20.37 %/day [15]. White shrimp have a greater average final weight that can be maintained at densities of 1,500, 3,000, and 4,500 ind/m³, but survival is significantly reduced at densities of 4,500 and 6,000 ind/m³. A density of 3,000 ind/m³ is considered optimal for enhancing white shrimp growth performance in the nursery phase using the biofloc technology system [2]. The average final weight of white shrimp cultivated in a clear water system is 0.64, 0.41, 0.31, and 0.17 g/ind, respectively, at shrimp densities of 1500, 3000, 6000, and 9000 ind/m³. Shrimp-specific growth rate (SGR) in clear water systems ranges between 9.7 and 11.8% per day, while in BFT systems, it ranges from 8.6–10.1% %/day [16]. The average weight of white shrimp maintained for 21 days in various ion mixture solutions ranges between 0.260-0.305 g/ind [17]. The specific growth rate of the white shrimp biofloc system when different carbon sources are added ranges between 8.1-10.1 %/day [18]. The average final weight of white shrimp maintained in nursery systems and at various densities ranges between 0.39-1.26 g/ind, with a daily weight growth rate of 9.27-12.5 %/day [19].

The density of cultivated organisms is a factor in determining their growth rate because it affects food competition and environmental utilization. Food is a critical growth factor [20]. Numerous studies indicate an inverse relationship between cultured shrimp growth performance and stocking densities [1]. Excessive stocking density during the nursery phase may have a detrimental effect on
shrimp growth and survival. This is due to some factors, including a decrease in available space and natural food, an increase in cannibalism, deterioration of water quality, and accumulation of organic matter at the pond's bottom [21].

![Figure 1](image-url)

**Figure 1.** Post larva-10 and juvenile of white shrimp produced on the nursery with a bottom aeration system

Aeration is used in the nursery to continue meeting the oxygen requirements of PL-shrimp vaname at a high density. The oxygen is used not only for breathing but also to oxidize organic matter in the rearing medium. Shrimp require oxygen to breathe. The amount of oxygen in the water has a significant effect on the life and growth of shrimp. Low oxygen levels can impair biological function, and in some cases, slow growth results in death [22].

### 3.2. Survival rate of white shrimp

The survival rate is the most critical parameter in intensive shrimp production during the nursery stage [21]. The average survival rate in the nursery of vaname shrimp with an aeration system was 86.40±0.56 percent in treatment A and 95.61±0.72 percent in treatment B, which is considered a high survival rate. This high survival rate was achieved through advancements made during the protrusion stage, including using superchargers to supply oxygen, using shelters to prevent cannibalism and proper feed management. Additionally, it is due to high-quality PL and reduced maintenance time (21 days). White shrimp survival rate (93.17 percent) after 15 days of rearing at a density of 4000 ind/m$^3$ [12]. The survival rate of white shrimp kept at a density of 2000 ind/m$^3$ for 14 days was 95.7% but decreased to 91.32% after 28 days [23]. White shrimp survival rate ranging from 76.67 -94.81% which was cultured for 30 days with different salinities (15–45 ppt) using an aquarium with a density of 6 ind/L [24]. White shrimp survival rates ranged from 76.67 to 94.81% when cultured for 30 days at various salinities (15–45 ppt) in a 6 ind/L aquarium [24]. For 21 days of rearing, the survival rate of white shrimp fed various feed combinations was 74.7-87.1% [14].

The survival rate of white shrimp in various rearing containers, specifically fiberglass containers, was 81.71–97.41%, happa containers in ponds were 61.51–80.36%, floating net cages (KJA) containers were 40–76%, and pond containers had the lowest survival rate of 30–50% [13]. For 25 days of rearing, the survival rate of white shrimp using the biofloc system with probiotics and various C/N ratios ranges between 86 and 94% [15]. The survival rate ranged from 85.0 to 98.4 percent for vaname shrimp reared for 42 days in a clear water recirculation system at a stocking density of 1,500-9,000 ind/m$^3$ [16]. White shrimp reared in the biofloc system for 28 days had a survival rate of 95.45 percent. The high survival rate was attributed to the nursery's brief duration [25]. Survival rates of white shrimp at various stocking densities with and without artificial substrates, specifically at a density of 1,500 ind/m$^3$ ranging from 50.3-53.6 percent and at a density of 3,000 ind/m$^3$ ranging from 52.0-53.8% [26]. Survival rates of white shrimp at various stocking densities with and without artificial substrates, specifically at a density of 1,500 ind/m$^3$ ranging from 50.3-53.6% and at a density of 3,000 ind/m$^3$ ranging from 52.0-53.8% [27]. The white shrimp postlarvae survival rate response in various ionic solutions over 21 days, specifically at salinities of 2 g/L ranging from 89.2-92.5 percent,
6 g/L ranging from 85.0-95.0 percent, and 15 g/L ranging from 89.0-94.0% [28]. White shrimp reared in a biofloc system for four weeks had a 93-99% survival rate when fed various feeds [29]. The survival rate of white shrimp reared in different densities ranged from 80.1-98.9%. White shrimp reared at various densities had a survival rate ranging from 80.1 to 98.9%. The lowest survival rate was achieved when spotting was treated using clear-water recirculating aquaculture systems (CW-RAS) at a density of 1,500 ind/m³ [19]. High stocking density creates competition for space, food, and dissolved oxygen, resulting in stunted growth and, in extreme cases, death.

3.3. Water quality

Water quality was critical in sustaining the growth and survival of aquaculture organisms. Shrimp's appearance is strongly influenced by complex environmental conditions, precisely water quality, for survival and growth. The results of observations made during the nursery phase on several quality variables are presented in Table 2.

### Table 2. Range of water quality variable’s values measured during 21 days rearing period

| Variable       | Treatment A (1,653 ind/m³) | Treatment B (909 ind/m³) |
|----------------|---------------------------|--------------------------|
| Temperature (°C) | 27.8 – 31.5               | 27.6 – 31.4              |
| DO (mg/L)       | 5.17-5.38                 | 5.32-6.67                |
| Salinity (ppt)  | 20-30                     | 20-30                    |
| pH             | 8.0-8.5                   | 8.0-8.5                  |
| Alkalinity (mg/L) | 110.7-147.6              | 114.8-147.6             |

The observations of water quality variables (Table 2), indicate that the water quality (temperature, dissolved oxygen, salinity, pH, and alkalinity) is still within the range necessary for white shrimp growth and survival. Temperature measurements in the two treatments were nearly identical, with the lowest temperature being 27.6 °C and the highest being 31.5 °C. The optimal temperature range for white shrimp culture is between 27 and 32 °C. Temperatures between 26 and 32 °C are optimal for vaname shrimp growth [31]. If the temperature exceeds the optimal level, the metabolism of the shrimp accelerates, increasing the need for dissolved oxygen. The temperature of the vannamei shrimp rearing media with dispensing system and variable density is 29.3-29.50 °C [19]. The water temperature of the white shrimp rearing media with various biofloc systems (heterotrophic, chemoautotrophic, and mature) ranges between 28.4-28.70 °C [27].

Salinity measurements of vaname shrimp pond water during the nursery phase revealed a range of 20-30 ppt. White shrimp grow well/optimally in the salinity range of 15-25 ppt, and some studies have shown that growth is still possible at a salinity of 5 ppt [32]. For optimal growth, young vaname shrimp aged 1-2 months require a 15-25 ppt; after that, growth is relatively good in the 5-30 ppt salinity range. The optimal salinity range for white shrimp is between 15-30 ppt [31].

The results of the dissolved oxygen measurement in the two treatment ponds were relatively similar, ranging between 5.17 and 6.67 mg/L. The ideal DO concentration for vaname cultivation is greater than 3 mg/L, with a tolerance of 2 mg/L [30]. The optimal range of dissolved oxygen was 3.5-7.5 mg/L [33]. Dissolved oxygen levels in vaname shrimp rearing media with biofloc systems varied between 4.99 and 6.12 mg/L with the addition of probiotics and different C/N ratios [15]. Dissolved oxygen concentrations in white shrimp rearing media containing various types of biofloc ranged between 5.9 and 6.3 mg/L [34]. Dissolved oxygen levels were 6.11-6.48 mg/L in white shrimp rearing at various densities [19].

The pH values of the water in the two treatment ponds ranged from 8.0 to 8.5. According to the findings of this observation, the pH of the shrimp culture media water is quite optimal. The optimal
pH range for vannamei cultivation is 7.3 to 8.5, with a tolerance range of 6.5 to 9 [30]. Water suitable for intensive white shrimp culture has a pH range of 7.4-8.9, with an optimal value of 8.0 [35]. The pH of the vanname shrimp rearing medium supplemented with probiotics, and a different C/N ratio ranged between from 7.52-7.63 [15]. The pH of the vannamei shrimp rearing medium supplemented with various types of biofloc varies between 7.7 and 8.2 [34]. The water pH used to breed vannamei shrimp with a heterotrophic, chemosynthetic, or mature biofloc system should be between 8.18 and 8.24 [27]. Alkalinity levels were measured in both treatments and ranged between 110.7 and 147.6 mg/L. That alkalinity condition remained viable and supported the white shrimp's life. The alkalinity of shrimp medium should be greater than 100 mg/L or between 120 to 160 mg/L [36]. The standard value for total alkalinity in pond water is 80 mg/L. If the pond water's alkalinity is low, it can be increased by adding lime [37]. The optimal alkalinity range is 90-150 mg/L [33].

4. Conclusions
The average final weight of white shrimp obtained was 0.292 g/ind and 0.320 g/ind at densities of 1,653 ind/m$^3$ and 909 ind/m$^3$, respectively. The average survival rate of white shrimp for 21 days of nursery with aerated system ranged from 86.40-95.61%. Water quality during maintenance including temperature, dissolved oxygen, salinity, pH and alkalinity were in a suitable range for growth and survival of white shrimp.

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