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Production performance of white shrimp *Litopenaeus vannamei* with super-intensive culture on different rearing densities

Kinerja produksi udang vaname *Litopenaeus vannamei* pada budidaya super intensif dengan padat penebaran berbeda

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ABSTRACT

This research aimed to evaluate the production performance of white shrimp *Litopenaeus vannamei* with super-intensive culture on different rearing densities. The research was conducted at PT. Dewi Laut Aquaculture, Cikelet, Garut, West Java. As many of 8 ponds were used and divided into 2 groups based on the stock density of shrimp, 550 ind/m^2 and 650 ind/m^2, and reared for 99 days. The results showed that super-intensive shrimp culture at the density of 550–650 ind/m2 potentially produced shrimp with average body weight ranged from 15.91–19.31 g, survival rate 62.67–87.95%, growth 0.16 to 0.20 g/day, FCR 1.35–1.66, and productivity reach 5.55–9.19 kg/m2. There were no significant differences between the two stocking densities in body weight, growth, and feed conversion performance, while ponds with higher rearing density had better survival and productivity than ponds with lower rearing density. *L. vannamei* cultured at a density of 650 ind/m^2 produces the best performance and most feasible to be applied in super-intensive white shrimp cultivation.

Keywords: *Litopenaeus vannamei*, super-intensive, high-density, production performance

ABSTRAK

Penelitian ini bertujuan untuk mengevaluasi kinerja produksi udang vaname pada sistem super- intensif dengan padat penebaran berbeda. Penelitian dilaksanakan di tambak PT. Dewi Laut Aquaculture, Cikelet, Garut, Jawa Barat, menggunakan 8 petak tambak. Tambak dibagi menjadi 2 kelompok, masing-masing 4 petak tambak dengan padat tebar udang 550 ekor/m^2 dan 4 petak tambak lainnya dengan padat tebar 650 ekor/m^2 dengan masa pemeliharaan 99 hari. Hasil penelitian menunjukkan bahwa budidaya udang vaname pada sistem super-intensif dengan padat tebar 550–650 ekor/m^2 dapat menghasilkan udang dengan bobot rata-rata berkisar antara 15.91–19.31 g, sintasan 62.67–87.95%, pertumbuhan 0.16–0.20 g/hari, konversi pakan (FCR) 1.35–1.66, dan produktivitas mencapai 5.55–9.19 kg/m^2. Tidak ada perbedaan nyata antara kedua padat penebaran pada kinerja bobot, pertumbuhan harian, dan FCR; sementara tambak dengan kepadatan tinggi memiliki nilai sintasan dan produktivitas yang lebih tinggi dari tambak dengan kepadatan rendah. Padat penebaran 650 ekor/m^2 menghasilkan kinerja produksi terbaik dan paling layak untuk diaplikasikan dalam budidaya udang vaname super-intensif.

Kata kunci : *Litopenaeus vannamei*, padat tebar tinggi, super-intensif, kinerja produksi

INTRODUCTION

White shrimp is one of the export commodities with high economical value (Herdianti *et al.*, 2015). Global white shrimp market demand is estimated to reach 5 million tons each year, while the industry is lacking the supply. Global production of shrimp is only 3.6 million tons and 2.37 million tons of it is white shrimp *Litopenaeus vannamei* which reared in brackish water (FAO GLOBEFISH, 2015). White shrimp production in Indonesia has supported the whole industry of white shrimp culture (Gunarto *et al.*, 2012). White shrimp is a famous species amongst shrimp farmers. It grows faster (Purba, 2012), relatively resistant to disease (Schock *et al.*, 2013; Umiliana *et al.*, 2016), high survival rate, a wide range of salinity tolerance (4–32 g/L) (Maicá *et al.*, 2014), and travels around the water column (Ernawati & Rochmady, 2017). It also exhibits efficient feeding (Umiliana *et al.*, 2016), can rear in high density (Wasielesky *et al.*, 2013), and high composition of meat (66–68%) compared to the tiger shrimp (62%) (Purba, 2012).

The high market demand of vannamei encourages the development of white shrimp culture, one of them is a floating cage net (Zarain-Herzberg *et al.*, 2010; Effendi *et al.*, 2016) and super-intensive culture. Various shrimp production is well-developing, starting from the high surface area and low-density culture to technology-based cultures, such as fertilization, feedings trays, and high stock density culture (Wasielesky *et al.*, 2006). Super -culture is the main focus of the future aquaculture using low volume, high stock density (Syah *et al.*, 2017; Krummenauer *et al.*, 2011; Wasielesky *et al.*, 2013), high productivity (Krummenauer *et al.*, 2011; Syah *et al.*, 2017), low wastewater (Syah *et al.*, 2017), and equipped with quarantine pond to treat the wastewater (Syah *et al.*, 2017).

Super-intensive shrimp culture is usually conducted in a small container with high density and a short-term rearing period (less than 40 days) (Wasielesky *et al.*, 2006; Maicá *et al.*, 2014). The latter method is combined with the two-step method, i.e. high density in the nursery phase and after several days, the shrimp will be moved to the grow-out phase with lower density (Vinatea *et al.*, 2010; Wasielesky *et al.*, 2013; Schock *et al.*, 2013). White shrimp culture with high density and long rearing period was done by Krummenauer *et al.* (2011) with 150-450 individuals/m^2 for 120 days. A super-intensive culture is expected to increase productivity. However, there is a certain level when the carrying capacity reaches the limit (Syah *et al.*, 2017). An excessive density influences the whole culture system which leads to failure as a consequence of enormous waste. This study was expected to evaluate the production performance of white shrimp in a super-intensive culture with two different densities as a standard to determine an optimal density of white shrimp culture.

MATERIALS AND METHODS

This study was held in September–December 2016. The shrimp culture was conducted in PT. Dewi Laut Aquaculture, Garut, West Java. It used eight ponds with 400 m^2 of average width and 3 m of depth. The experimental ponds were categorized into two groups, i.e. four ponds with 550 individuals/m^2 (T550) and four ponds with 650 individuals/m^2 (T650). The result by Krummenaur *et al.* (2011) was used to determine the treatments in this study. It was possible to increase the density beyond 450 individuals/m^2 due to the sufficient result by Krummenaur *et al.* (2011).

The pond construction was covered by HDPE plastic with 0.75 mm of thickness. It was also furnished with a central drain, one blower with 7.5 horsepower (HP), and four paddle wheel with 1 HP each (Figure 1). A 1 HP of paddle wheel facilitates 16 kg of feeding per day with maintaining dissolved oxygen content amongst 3 mg/L and targeted biomass around 550–600 kg (Hopkins *et al.,* 1991). The water level was filled up to 2.5 m depth, followed by 15 mg/L of *trichloroisocyanuric acid* (TCCA), 25 mg/L of saponin, 1 mg/L ZA fertilizer, 1.5 mg/L of molasse, 5 mg/L of dolomite, and 0.1 g/m^2 of commercial probiotics (*Bacillus* sp., *Thiobacillus* sp.*, Nitrosomonas* sp.*,* and *Nitrobacter* sp.) to grow plankton and form flocs for 12 days. Particularly, the probiotics were delivered every two weeks during the culture.

The tested seed used in this study was specific pathogen-free (SPF) post larvae 9 from Lampung Province. They were reared in the pond for 100 days based on the treatment using a semifloc system. The tested post-larvae were fed using crumble feed with 40% of protein content in the initial phase, then changed to a pellet with 36% of protein content after 20 days. It was based on the standard of white shrimp farming. In the first month of study, the blind feeding method was applied. Blind feeding is established according to survival and average weight estimation, also feeding rate (15% of total biomass). The percentage was declined to 5%, 4%, and 3% for the second, third, and fourth month, respectively. Feeding frequency was carried out six times a day. During the rearing period, water discharge and siphoning were completed regularly to eliminate uneaten feed and organic waste on the bottom of the pond. Partial harvest was conducted as many as 25% of the biomass on day 60 dan 75. On the contrary, the total harvest was done on day 99.

Tested parameters

The tested parameters consisted of average body weight (ABW), average daily weight (ADG), survival, feed conversion ratio (FCR), and productivity. ABW and ADG were measured regularly after 30 days of rearing by collecting 30–40 shrimp in each pond every seven days. Survival, FCR, and productivity were calculated at the end of the study. The following formulas are used to calculate ABW, ADG, survival, FCR, and productivity (Maicá *et al.*, 2014).

Average body weight (ABW)

ABW is a ratio between individual bodyweight and population weight. It is calculated using the following formula.

$$ABW = \frac{\sum \text{shrimp weight (g)}}{\sum \text{shrimp population (g)}}$$

Average daily gain (ADG)

ADG is daily weight addition in a certain time. It is calculated using the formula below.

$$ADG = \frac{ABW_t - ABW_0}{H}$$

ABW_t = final average weight (g)
ABW_0= initial average weight (g)
H = rearing period (day)

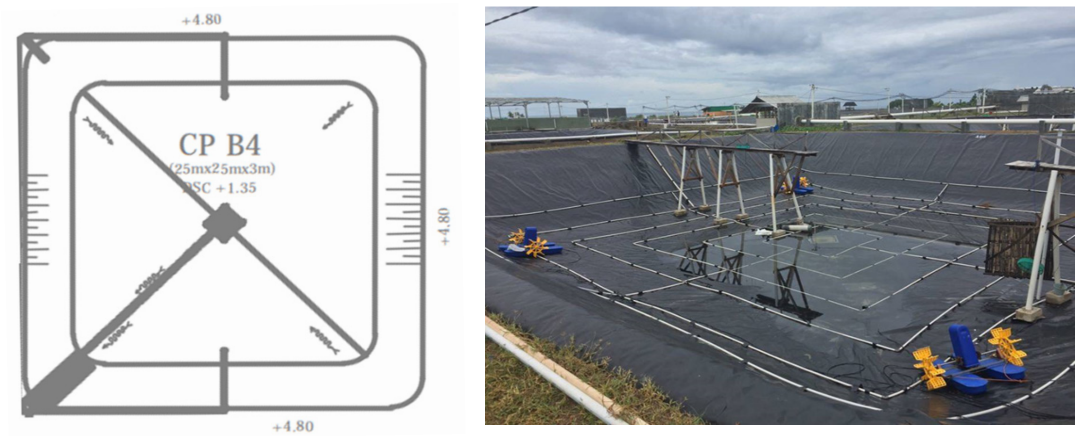

Figure 1. Experimental pond construction

Table 1. Shrimp population and density each ponds.

No	Pond code	Wide (m^2)	Population (individual)	Density (ind/m^2)
Group I (T550)				
1	A2	407	222,528	547
2	A3	410	222,528	543
3	A5	406	226,452	558
4	A10	408	225,122	552
	Average	408	224,158	550 ± 6.49
Group II (T650)				
1	A2	395	256,891	650
2	A3	410	266,585	650
3	A5	395	257,580	652
4	A10	437	282,384	646
	Average	409	265,860	650 ± 2.50

Survival rate

Survival is the percentage of the survived population at the end of the study. It was calculated by dividing the final population and initial population.

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

SR = Survival (%)
Nt = Final population
No = Initial population

Feed conversion ratio (FCR)

FCR is a mathematical relationship between total feed and biomass gained by consuming it. It was calculated using the following formula.

Productivity

In this study, productivity was measured based on a unit of pond-wide. The following formula was used to determine productivity. Water quality parameters in this study were temperature, dissolved oxygen (DO), pH, salinity, total ammonia nitrogen (TAN), nitrite (NO_2^-), nitrate (NO_3^-), phosphate (PO_4), and total organic matter (TOM). Temperature, DO, and pH was measure daily every morning, afternoon, and evening. Meanwhile, salinity, TAN, phosphate, and TOM were measured every week, twice a day.

Data analysis

The growth parameters were analyzed statistically using Repeated Measures ANOVA through IBM SPSS Statistics 20 to determine the significant difference amongst treatments. The rest of the data were described descriptively to discover the biological response of the white shrimp and characteristics of the aquatic environment.

RESULTS AND DISCUSSION

The T550 treatment resulted in survival ranged from 62.67–87.95% and ABW was 15.91–19.31 g. The ADG, FCR, and productivity ranged from 0.16–0.20 g/day, 1.35–1.66, and 5.55–7.54 kg/m^2, respectively. Meanwhile, the T650 treatment presented 79.97–87.34% of survival, 16.50–17.91 g of ABW, and 0.17–0.19 g/day of ADG. FCR and productivity ranged from 1.38–1.49 and 7.87–9.19 kg/m^2 (Table 2). Those results were in line with Krummenauer *et al.* (2011) who conducted white shrimp culture in a biofloc system with 150, 300, and 450 ind/m^2 of density for 120 days. He reported that the survival was around 75–92 %, ABW was 9–16.8 g, ADG ranged from 0.07–0.13 g/day, FCR extended in 1.29–2.41, and productivity differed between 2.15–4.09 kg/m^2.

The water quality parameter indicated a supportive environment condition to the white shrimp. There was no intense difference amongst the treatment. The temperature was relatively 26–32°C, dissolved oxygen was 4.0–8.3 mg/L, and pH was 7.3–8.9. Total ammonia nitrogen, nitrite, nitrate, phosphate, and organic matter extended from 0.5–5 mg/L, 0.1–25 mg/L, 1–150 mg/L, 0.3–3 mg/L, and 38–126 mg/L, respectively (Table 3).

Table 2. White shrimp production in super intensive system

Density (ind/m^2)	Pond ID	Biomass (kg)	SR (%)	ABW (g)	ADG (g)	FCR	Productivity (kg/m^2)
550	A2	3,069.11	76.60	19.31	0.20	1.35	7.54
	A3	2,889.08	73.12	19.24	0.19	1.45	7.05
	A5	2,255.03	62.67	17.29	0.17	1.66	5.55
	A10	2,924.08	87.95	15.91	0.16	1.36	7.17
Average		2,784.33 ± 361.37^a	75.09 ± 10.42^a	17.93 ± 1.64^a	0.18 ± 0.02^a	1.45 ± 0.14^a	6.83 ± 0.87^a
650	B4	3,109.53	79.97	16.94	0.18	1.46	7.87
	B7	3,400.39	80.22	17.72	0.19	1.43	8.29
	B8	3,629.34	87.34	17.91	0.18	1.38	9.19
	B10	3,574.08	85.04	16.50	0.17	1.49	8.18
Average		3,428.34 ± 233.85^b	83.14 ± 3.64^b	17.27 ± 0.66^a	0.18 ± 0.01^a	1.44 ± 0.05^a	8.38 ± 0.57^b

Note: Different superscript letter in the same column indicates significant different (P<0.05).

According to Table 4, it was clearly described that there was no significant difference amongst treatment in ABW, ADG, and FCR (P>0.05). On the contrary, survival dan productivity indicated a significant difference amongst treatments (P<0.05). The T550 treatment presented a slightly greater result compared to the T650. Even though, there was no significant result on both ABW and ADG (Table 4). A tolerable environment was assumed to support the white shrimp culture.

Figure 2 explained that the daily growth of the white shrimp was relatively identical until day 40. Some sort of contrast were started to appear after day 40 that leads to a greater result in T550. The growth of white shrimp was straightly affected by the density. When the density went higher, the growth was likely lessened. Several former studies support the result, i.e. Balakrishnan *et al.* (2011), Krishna *et al.* (2015), Budiardi *et al.* (2005), and Krummenauer *et al.* (2011).

Both treatments presented greater ADG (0.18 ± 0.02 g/day) compared to Krummenauer *et al.* (2011) (0.12, 0.13, and 0.07 g/day) with 150, 300, and 450 ind/m^2 of density. A similar result was described by Syah *et al.* (2017) (0.20 ± 0.01 g/day) who reared white shrimp in 700, 1000, and 1200 ind/m^2 of density. Those results indicated that white shrimp was relatively tolerant towards high density. Budiardi *et al.* (2005) stated that the density will affect the competition amongst individuals, in terms of area, food, and oxygen. However, the ability of white shrimp to utilize the entire water column, tolerable water condition, and adequate nutrition supply also positively contributed to weight gain without being disturbed by the density (Syah *et al.*, 2017). Wasielesky *et al.* (2013) reported that the aborted white shrimp for 35 days which reared in 1500–6000 ind/m^2 reported no significant weight gain compared to the 300 ind/m^2 of density.

The T550 treatment produced lower survival than the T650 treatment. This opposed the result by Budiardi *et al.* (2005), Krummenauer *et al.* (2011), Krishna *et al.* (2015), and Syah *et al.* (2017) who confirmed that higher density would lead to lower survival. Nevertheless, diverse survival could appear as well, e.g. Ernawati and Rochmady (2017). They used various densities, i.e. 9, 14, 19 ind/container and the survival was 70.37%, 78.57%, and 74.27%, respectively. Ernawati and Rochmady (2017) suggested that the highest survival was considered as the

Table 3. Water quality result.

Water quality parameter	Treatment		Threshold	Reference
	T550	T650		
Temperature (°C)	26–32	26–32	20–32	González *et al.*, 2010
Dissolved Oxygen (mg/L)	4.00–6.80	4.0–8.3	≥ 4	Cobo *et al.*, 2014
pH	7.5–8.8	7.3–8.9	6–9	Boyd, 1989
Salinity (g/L)	21–26	21–26	20–45	Chong-Robles *et al.*, 2014
TAN (mg/L)	0.5–5	0.5–5	≤ 13.2	Cobo *et al.*, 2014
			≤ 28.2	Schuler *et al.*, 2010
Nitrite (mg/L)	0.1–25	0.1–25	≤ 163.3	Schuler *et al.*, 2010
Nitrate (mg/L)	1–150	1–125	≤ 220	Khun *et al.*, 2010
Phosphate (mg/L)	0.3–3	0.3–3	≤ 390.55	Na *et al.*, 2009
Total organic matter (mg/L)	38–126	25–125	< 500	Gaona *et al.*, 2011

Table 4. Production performance of white shrimp with different densities.

Production performance	Treatment	
	T550	T650
Survival rate/SR (%)	75.09 ± 10.42^a	83.14 ± 3.64^b
Average body weight/ABW (g)	17.93 ± 1.64^a	17.27 ± 0.66^a
Average daily growth/ADG (g/day)	0.18 ± 0.02^a	0.18 ± 0.01^a
Feed conversion ratio/FCR	1.45 ± 0.14^a	1.44 ± 0.05^a
Productivity (kg/m^2)	6.83 ± 0.87^a	8.38 ± 0.57^b

Note: Different superscript letter in the same row indicates significant different (P<0.05).

optimum survival because no food and movement competition triggered cannibalism amongst individuals. In this study, the T650 treatment was considered as an acceptable density for white shrimp culture. Also, the dissolved oxygen and nitrate in the T650 treatment were slightly better.

The FCR in this study did not differ significantly (P>0.05) amongst treatments (Table 4). It was different from Budiardi *et al.* (2005) who reported that shrimp that culture in low density (72–73 ind/m^2) showed lower FCR compared to the higher density (93–105 ind/m^2). However, various FCR was also shown in several studies, such as Krummenauer *et al.* (2011) with 150, 300, and 450 ind/m^2 of stocking density and Syah *et al.* (2017) with 750, 1000, and 1250 ind/m^2. Live feed supply tends to decrease when the density grows higher so that shrimp will rely on the artificial feed even more (Budiardi *et al.*, 2008; Mangampa & Suwoyo, 2010). As a result, shrimp culture with high density is required to estimate the population accurately. It is essential to avoid excessive feeding that possibly leads to high FCR.

Productivity is the harvested biomass in a certain wide unit. Productivity increases along with biomass. In this study, the T650 treatment showed greater productivity compared to the T550. On the contrary, Budiardi *et al.* (2005) reported that lower density showed higher productivity. In this case, the T650 treatment still presented excellent productivity, so that the biomass was high as well. Fleckenstein *et al.* (2020) stated that stocking density directly affected shrimp production significantly. It was possible because the water quality parameter in the T650 still supported the shrimp culture system, especially dissolved oxygen, temperature, pH, and salinity (Table 3). It showed that the productivity strongly increased along with the density continuously until a certain level of carrying capacity in an aquatic environment.

Ammonia-nitrogen content and organic matter in both treatments were relatively high. Although it was tolerable for shrimp culture (Cobo *et al.*, 2014; Schuler *et al.*, 2010). Ammonia is a toxic output of organic matter demolishing. Ammonia toxicity declines when the dissolved oxygen raising (Barbieri, 2010). A high level of ammonia is distinctly influenced by the density due to the high waste of feces and uneaten feed. Super-intensive culture often faces eutrophication due to excessive nutrient and organic waste (Nguyen *et al.*, 2019; Nguyen *et al.*, 2020). Nevertheless, nitrification was run by the bacteria to maintain the ammonia-nitrogen content. *Nitrosomonas* sp. and *Nitrobacter* sp. oxidated ammonia-nitrogen, so that it changed into nitrite and nitrate. Nitrate is the final result of nitrification which later will be benefited by phytoplankton (Herdianti *et al.*, 2015).

Thereafter, high density demands more feed. Excessive feed triggers higher pollutants, e.g. uneaten feed and metabolic waste (Budiardi *et al.*, 2005). Organic matter accumulation produces ionic iron, hydrogen sulfide, and reduced compounds, which are lethal for shrimp Boyd (1989). In line with Budiardi *et al.* (2005), Khoa *et al.* (2020) stated that high density induced a higher concentration of microbes due to the abundant nutrition in the water. Dissolved oxygen demand

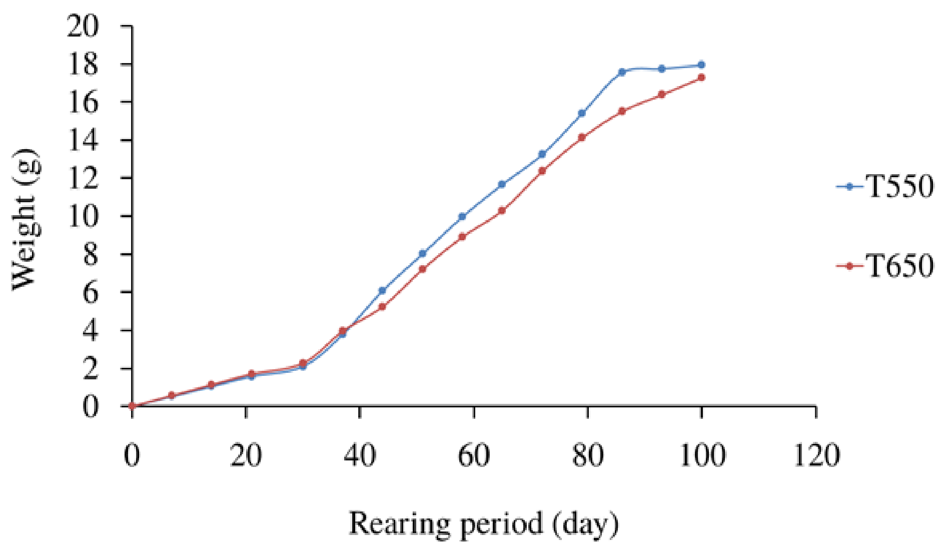

Figure 2. White shrimp growth in various density

and suspended solid will elevate and the turbidity will also affect shrimp growth (Fleckenstein *et al.*, 2020). However, the water quality results in this study were kept in tolerable range, so that eutrophication in the pond ecosystem did not influence shrimp survival, growth, and biomass significantly (González *et al.*, 2010; Cobo *et al.*, 2014; Boyd, 1989; Chong-Robles *et al.*, 2014; Schuler *et al.*, 2010; Khun *et al.*, 2010; Na *et al.*, 2009; Gaona *et al.*, 2011). Gaona *et al.* (2011) declared that organic matter can be reduced when the culture system is well-managed. A decreased organic waste will lead to the excellent water condition. Furthermore, shrimp culture with a greater growth will be fully supported (Gaona *et al.*, 2011). Overall, we can conclude that high-density shrimp culture was applicable with advanced environmental management.

CONCLUSION

There was no significant difference amongst treatments in terms of ABW, ADG, and FCR. On the contrary, survival and productivity showed a significant result in the T650 treatment. We can conclude that the T650 treatment was considered applicable in super-intensive shrimp culture.

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