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Growth and survival rates of domesticated and non-domesticated breeding stocks of *Penaeus monodon* Fabricius, 1798 cultured in ponds and tanks

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Abstract

Sourced breeders from domesticated broodstocks have played an essential role in the steady development of shrimp culture in many countries. In the present study, two experiments were performed in Tra Vinh province, Vietnam, to compare the culturing benefits of sourced breeding stocks from domesticated and non-domesticated *Penaeus monodon* broodstock. The first 90-day experiment was randomly arranged with three repetitions in six earthen ponds (1,500–2,000 m^2). Experimental shrimp (PL12) were stocked at a density of 20 ind. m^{-2}. The second experiment was randomly designed with three repetitions in six composite tanks (6.0 m^3). PL15 of experimental shrimp were cultured at a density of 30 ind. m^{-2} for 120 days. Grobest pellet feed (40 % protein) was used in both experiments. At experiment termination, the mean weight (26.09 g) and length (15.68 cm) under pond culture, as well as respective values of 15.57 g, and 13.21 cm under tank culture, for D-shrimp were significantly higher than those of W-shrimp ($p<0.05$). Similarly, the survival rate (84.33 %), FCR (0.98), and yield (3,558 kg ha^{-1}) under pond culture, as well as the survival rate (87.59 %) and yield (470 g m^{-3}) under tank culture, of D-shrimp were significantly better than those of W-shrimp ($p<0.05$). These results prove that the grow-out culture of shrimp postlarvae from domesticated broodstocks resulted in superior performance to those from wild broodstocks.

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Introduction

Shrimp is a favored food in daily meals and represents a significant commercial item, accounting for approximately 15.5 % of the total value of seafood products in global markets. From farmed shrimp sources in around 60 countries, the annual mean growth rate of shrimp production achieved more than 20 % every year from 2000 to 2016, making it one of the fastest-growing commodities in the food sector (Flaaten, 2018), reaching a production level of 4.569 million tons in 2021 (Chase, 2022). The black tiger shrimp is a native penaeid shrimp and has been widely cultured in Southeast Asia (Ekmaharaj, 2018) due to its commercial culturing advantages, such as relatively high and stable prices (FAO, 2019) and better resource-use efficiency (Nisar, Zhang, Navghan, Zhu, & Mu, 2021) when compared to white leg shrimp (*Litopenaeus vannamei*). In 2018, these shrimp accounted for 12–15 % of the global cultured shrimp production (FAO, 2019).

Vietnam, which possesses more than 1.7 million hectares of water surface area, has great potential for aquaculture (VASEP, 2019). Since the Vietnamese government enacted a policy shift from rice monoculture production in saline-affected land areas to aquaculture in 2000, some agricultural areas in the Mekong River Delta, Vietnam, have experienced permanent salinity intrusion. As a result, marine shrimp farming in Vietnam has strongly developed in a farming area, degree of intensification, and production (Trang, Khai, Tu, & Hong, 2018). In 2019, Vietnam's total area of shrimp farming was ~750,000 hectares with an output of nearly 900,000 tons, of which the Mekong Delta accounted for more than 70 % of the nation's total area of shrimp farming (~600,000 hectares) with an output of ~750,000 tonnes (GSO, 2021). Vietnam's shrimp culture production has contributed to approximately 40–45% of its total value of exported seafood—accounting for around 9% of exported shrimp products worldwide—and earned 3.85 billion USD in 2018. This made Vietnam the second-largest shrimp supplier globally in the same field(VASEP, 2021). The two main cultured marine shrimp species in Vietnam are black tiger shrimp and white leg shrimp (Van Duijn et al., 2012). In 2017, the culture area for black tiger shrimp in Vietnam was 622,400 hectares, out of a total brackish shrimp culture area of 721,100 hectares nationwide (VASEP, 2018).

Although *P. monodon* is the native shrimp and major cultured species with a relatively long culturing practice in Vietnam, cultured breeding stocks have been produced almost exclusively from broodstocks that were wild-caught or chosen from commercial culturing ponds (generally called wild broodstocks). Shrimp farming, which has mainly been reliant on wild broodstock sources, has shown an unsustainable situation due to issues such as genetic diversity loss, a decrease in the environmental adaptability of the species, the exhaustion of broodstock sources (Dixon et al., 2008; Liu, Zhou, Li, & Lu, 2013), and the risks of vertical dismission from broodstocks to offspring resulting in disease outbreaks (Craig, 1998; Yano, 2000; Coman et al., 2005). Previous studies on the broodstock domestication of penaeid shrimp species indicated that benefits were achieved by reducing exotic pathogen risks, alleviating broodstock shortages, and creating pathogen-free and expectant gene breeding stocks (Gjedrem & Fimland, 1995; Flegel, Booyaratpalin, & Withyachumnarnkul, 1997; Groumellec, 2008; Hoa, 2009; Huong et al., 2020). Recently, shrimp farming in Vietnam—as in many countries—has faced risks from epidemic outbreaks, poor water source quality, the adverse effects of climate change, and broodstock source depletion. Therefore, studies on the broodstock domestication of native penaeid species (e.g., *P. monodon*) have received significant attention from Vietnamese shrimp producers (Huong et al., 2020).

For the first time in Vietnam, Hoa (2009) performed a study on the broodstock domestication of *P. monodon* in captivity to develop techniques to close the life cycle from egg to broodstock to create domesticated *P. monodon* spawners that were capable of producing offspring through several generations. In 2019, as part of a ministerial marine shrimp research project of the Vietnamese government, researchers from Tra Vinh University studied the domestication of *P. monodon* broodstock in a water-circulated composite tank system. They produced postlarvae stocks that were healthy and free of pathogens (i.e., IHHNV, WSSV, MBV, TSV, YHV, and HPV). The study results were published by Huong et al. (2020) and Truc et al. (2021). Due to suspicions about the natural culturing adaptability of captivity-domesticated *P. monodon* breeding stocks, they have not yet been widely used for commercial culturing in Vietnam. The present study used the domesticated *P. monodon* breeding stock that was part of the product in the study of Huong et al. (2020) for culture in earthen ponds and composite tanks to evaluate its culturing benefits in terms of growth performance, survival rate, and yield in different culturing systems. This work was done to make practical recommendations for the future use of sourced *P. monodon* breeding stock from domesticated broodstock in grow-out culture.

Materials and Methods

Experimental materials.

The experimental shrimp sources consisted of the following: (1) postlarvae sourced from domesticated broodstock (D-shrimp) obtained from the product of Huong et al. (2020) (pond culture) and the commercial, domestic breeding stocks of the Research Institute for Aquaculture No. 2 (RIA2) under the Ministry of Agriculture and Rural Development of Vietnam (tank culture); (2) postlarvae sourced from non-domesticated broodstock (W-shrimp) that were collected from a local shrimp hatchery. Both were tested as pathogen-free (WSSV, YHV, and MBV) and acclimated to adapt to the conditions of each experiment before being used.

A Grobest commercial feed (made in Vietnam) containing the major nutritional compositions of protein ≥ 42%, lipid ≥ 6.0%, and fiber ≤ 3.0% was supplemented with digestive enzymes, minerals, and vitamin C, which were utilized in two experiments. The US National Research Council's guide for the Care and Use of Laboratory Animals was followed.

Experiment 1: comparing the growth and survival rate of sourced black tiger shrimp breeding stocks from domesticated and non-domesticated broodstock cultured in earthen ponds. This experiment aimed to compare the culturing benefits of D-shrimp and W-shrimp in a system of earthen ponds. The investigation was randomly conducted with three repetitions in six rectangular earthen ponds (area of 1,500–2,000 m^2, water depth of 1.2 m, salinity of 10 g L^{-1}) at farm households in Truong Long Hoa Commune, Duyen Hai District, Tra Vinh Province (southeast of Vietnam) from February to May 2019. W-shrimp and D-shrimp postlarvae at the 12-day stage (PL12) with a mean weight of 0.02 g $ind.^{-1}$ and mean length of 1.30 cm $ind.^{-1}$ were stocked at a density of 20 ind. m^{-1} and fed four times per day (6:00, 10:00, 14:00, and 18:00) with a feeding ratio based on recommendations from the manufacturer for different developmental stages of *P. monodon*. The diluted pellet feed was spread throughout the ponds in the first month.

In the following months, the shrimp were fed pellets. Feeding trays monitored the shrimp's feed consumption and health status to adjust to a suitable diet. The two 1.5 HP paddlewheel aerators (ten propellers) in each culturing pond were regularly operated to ensure that the dissolved oxygen concentrations in the ponds were at reasonable levels for the shrimp. The pond water was periodically exchanged (20–30% of volume every month) with prepared water through a settling pond. The culturing period lasted 90 days. Every three months, samples for calculating growth performance were randomly obtained from 30 shrimp per pond. Data on survival rate, feed conversion ratio, and yield were collected at the end of the experiment.

Experiment 2: comparing the growth and survival rate of sourced black tiger shrimp breeding stocks from domesticated and non-domesticated broodstock cultured in composite tanks. This 120-day experiment with a completely randomized design and three repetitions was conducted at the experimental hatchery of Tra Vinh University, Vietnam, from May to September 2020 to compare the culturing benefits of D-shrimp and W-shrimp in composite tanks. W-shrimp and D-shrimp postlarvae at the 15-day stage (PL15) (mean weight = 0.04 g $ind.^{-1}$, mean length = 1.9 cm $ind.^{-1}$) were stocked at a density of 30 ind. m^{-2} in six-round composite tanks (area of 6.0 m^3, water depth of 1.0 m, salinity of 10 g L^{-1}) indoors and fed five times per day (7:00, 11:00, 15:00, 19:00, and 23:00). Any uneaten feed, shells, and feces in the tanks were siphoned twice a day for removal. Tanks were then resupplied with new water to the initial volume. During culturing, water in the tanks was continuously aerated and changed (30% of the water volume) every ten days in the first month and once per day in the following months. In addition, PondPlus probiotic (Bayer, Germany) was also used in the culturing tanks at the manufacturer's recommended dosage. Growth performance data were randomly collected every month by sampling 30 shrimp per tank for weight and length measurements. The survival rate and biomass were determined after 120 days of culture.

Data collection.

Water quality was controlled before and during the cultivated period. Namely, a thermometer measured temperature and pH daily at 7:00 and 14:00. Nitrites, alkalinity, and TAN were checked every three days at 14:00 using a Sera GH test kit (Germany).

In both experiments, weight and length parameters were measured by an electrical analytical balance of 0.01 g and a divided ruler in millimeter units.

Data calculation

Daily weight gain (g day^{-1}) = final weight – initial weight/Culturing days

Daily length gain (cm day^{-1}) = final length – initial length/Culturing days

Specific growth rate in weight (% day^{-1}) = [(Ln final weight) – (Ln initial weight)]/Culturing days × 100

Specific growth rate in length (% day^{-1}) = [(Ln final weight) – (Ln initial weight)]/Culturing days × 100

Survival rate (%) = (Final number/Initial number) × 100

Feed conversion ratio (FCR) = Consumed feed (g)/Weight gain (g)

Yield (g m^{-3}) = Shrimp biomass/culture volume for tank culture.

Yield (kg ha^{-1}) = Total production (kg) /Culture area (ha)

Data analysis

All data were processed to obtain descriptive statistics (average value and standard deviation). T-tests were used to compare the statistical differences between mean values via SPSS 20.0 software.

Results

Water quality parameters.

The water quality parameters investigated in both experiments fluctuated within the suitable range for *P. monodon* during the culturing period. Notably, the values of each parameter were not significantly different between the D-shrimp and W-shrimp culturing ponds or tanks. In the first experiment, the following ranges were observed: temperature, 29.6–29.8 °C; pH, 8.0–8; TAN, 0.49–0.77 mg L^{-1}; nitrite, 1.22–1.32 mg L^{-1}; alkalinity, 146.0–217.1 mg L^{-1}. In the second experiment, the following ranges were observed: temperature, 28.7–29.5 °C; pH, 8.0–8.1; TAN, 0.29–0.38 mg L^{-1}; nitrite, 1.31–1.34 mg L^{-1}; alkalinity, 151.1–155.2 mg L^{-1}.

Performance of shrimp cultured in earthen ponds.

The growth performance results of shrimp during 90 days of culture are shown in **Figures 1-2** and **Table 1**. After 90 days of culture, the mean weight (26.09 g) and length (15.68 cm) of D-shrimp were significantly higher than those of W-shrimp (20.25 g and 12.55 cm, respectively) (**Figures 1-2**).

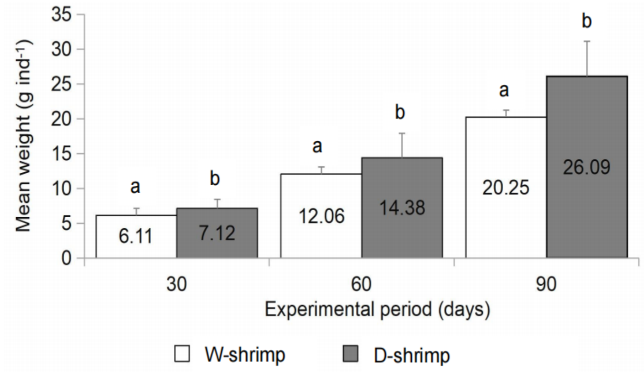

Figure 1 Mean weight of domesticated and non-domesticated *Penaeus monodon* shrimp cultured in earthen ponds during the 90-day period
[The different bars with different letters (a, b) at the same sampling time in Figures show a significant difference ($p < 0.05$)]

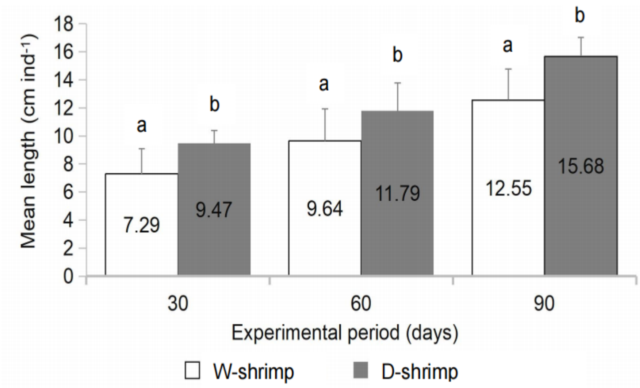

Figure 2 Mean length of domesticated and non-domesticated *Penaeus monodon shrimp* cultured in earthen ponds during the 90-day period
[The different bars with different letters (a, b) at the same sampling time in Figures show a significant difference ($p < 0.05$)]

At 30, 60, and 90 culturing days, D-shrimp achieved daily weight gains of 0.23, 0.24, and 0.39 g day^{-1}, respectively, and specific growth rates (in weight) of 16.47, 2.30, and 2.03 % day^{-1}, respectively. In W-shrimp, these parameters were 0.20, 0.19, and 0.27 g day^{-1} for daily weight gain and 15.87, 2.24, and 1.84 % day^{-1} for specific growth rates (in weight) at 30, 60, and 90 culturing days, respectively. The values of D-shrimp were consistently higher and significantly different compared to those of W-shrimp. There was a slight decrease in the daily weight gain of W-shrimp, while this indicator increased slightly in the first 30 culturing days for D-shrimp (**Table 1**).

Table 1 Daily weight gain and specific growth rate in the weight of domesticated and non-domesticated *Penaeus monodon* shrimp cultured in earthen ponds during the 90-day period.

Time (day)	30	60	90
	Daily weight gain (g day^{-1})		
W-shrimp	0.20± 0.06^{a}	0.19±0.14^{a}	0.27±0.20^{a}
D-shrimp	0.23±0.40^{b}	0.24±0.12^{b}	0.39±0.18^{b}
	Specific growth rate in weight (% day^{-1})		
W-shrimp	15.87±0.06^{a}	2.24±1.45^{a}	1.84±1.37^{a}
D-shrimp	16.47±0.04^{b}	2.30±0.91^{a}	2.03±0.89^{a}

Values are presented as mean±SD. Values with different superscript letters (a, b) in the same columns show a significant difference ($p < 0.05$).

At the end of the experiment, the survival rate (84.33%), feed conversion ratio (0.98), and yield (3,558 kg ha^{-1}) of D-shrimp were significantly better than those of the W-shrimp, with corresponding values of 82.0%, 1.32, and 2,504 kg ha^{-1}, respectively ($p < 0.05$) (**Table 2**).

Table 2 Survival rate, feed conversion ratio, and yield of domesticated and non-domesticated *Penaeus monodon* shrimp cultured in earthen ponds after 90 days.

	Survival rate (%)	Feed conversion ratio	Yield (kg ha^{-1})
W-shrimp	82.00±2.00^a	1.32±0.08^b	2,504±212.85^a
D-shrimp	84.33±4.51^b	0.98±0.07^a	3,558±182.04^b

Values are presented as mean±SD. Values with different superscript letters (a, b) in the same columns show a significant difference ($p < 0.05$).

Performance of shrimp cultured in composite tanks.

After 120 days of culture, the growth performance parameters consisted of mean weight of 15.57 g ind^{-1} with a daily weight gain of 0.23 g day^{-1} and a specific growth rate in the weight of 1.87% day^{-1}; and a mean length of 13.21 cm ind^{-1} with a daily length gain of 0.94 cm ind^{-1} and a specific growth rate in the length of 0.79% day^{-1} of D-shrimp were significantly higher than those of W-shrimp, with corresponding values of 5.75 g ind^{-1}, 0.03 g day^{-1}, and 0.71% day^{-1}; and 9.33 cm ind^{-1}, 0.42 cm ind^{-1} and 0.53% day^{-1}. A similar pattern was observed for shrimp during the period of culture; that is, the growth parameters of D-shrimp were always significantly higher than those of W-shrimp at the sampling times after every 30 days of culture ($p<0.05$) (**Table 3–4**).

Table 3 Weight growth performance of domesticated and non-domesticated *Penaeus monodon* shrimp cultured in composite tanks during the 120-day period

Parameters	W- shrimp	D-shrimp
Mean inital weight (g ind^{-1})	0.03±0.01^a	0.04±0.01^a
30 days mean weight (g ind^{-1})	0.25±0.14^b	0.58±0.23^a
60 days mean weight (g ind^{-1})	1.16±0.56^b	5.13±1.50^a
90 days mean weight (g ind^{-1})	4.74±1.85^b	8.81±1.65^a
120 days mean weight (g ind^{-1})	5.75±1.69^b	15.57±3.70^a
Daily weight gain (g day^{-1})	0.03±0.09^b	0.23±0.14^a
Specific growth rate in weight (% day^{-1})	0.71±0.25^b	1.87±0.98^a

Values are presented as mean±SD. Values with different superscript letters (a, b) in the same rows show a significant difference ($p < 0.05$).

Table 4 Length growth performance of domesticated and non-domesticated *Penaeus monodon* shrimp cultured in composite tanks during the 120-day period

Parameters	W-shrimp	D-shrimp
Mean inital length (cm ind^{-1})	1.4±0.20 ^{a}	1.9±0.10 ^{a}
30 days mean length (cm ind^{-1})	3.15±0.41^a	4.30±0.51^b
60 days mean length (cm ind^{-1})	5.11±0.85^a	8.88±0.89^b
90 days mean length (cm ind^{-1})	8.05±1.38^a	10.41±0.62^b
120 days mean length (cm ind^{-1})	9.33±0.77^a	13.21±1.12^b
Daily length gain (cm day^{-1})	0.42±0.56^a	0.94±0.41^b
Specific growth rate in lenght (% day^{-1})	0.53±0.68^a	0.79±0.34^b

Values are presented as mean±SD. Values with different superscript letters (a, b) in the same rows show a significant difference ($p < 0.05$).

At the end of the experiment, the survival rate (87.59%) and the biomass (470 g m^{-3}) of D-shrimp were significantly higher than those of W-shrimp (64.17% and 101 g m^{-3}, respectively) ($p < 0.05$) (**Figure 3–4**).

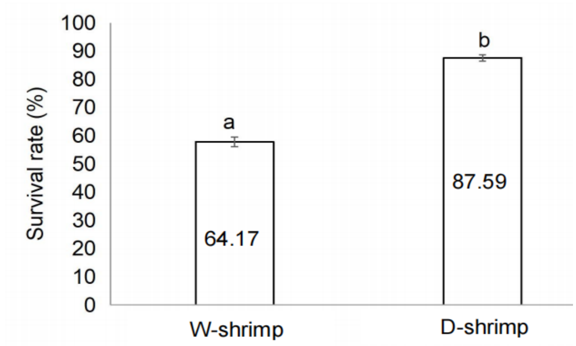

Figure 3 Survival rate of domesticated and non-domesticated *Penaeus monodon* shrimp cultured in composite tanks after the 120 days
[The bars with different letters (a, b) in Figures show a significant difference ($p < 0.05$)]

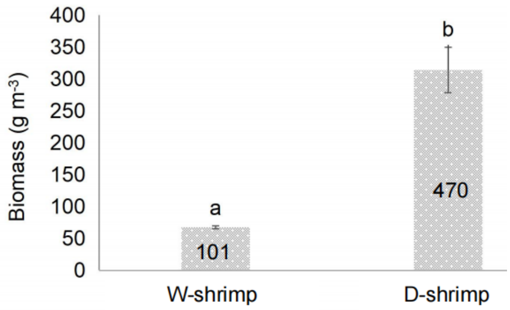

Figure 4 Yield of domesticated and non-domesticated *Penaeus monodon* shrimp cultured in composite tanks after the 120 days
[The bars with different letters (a, b) in Figures show a significant difference ($p < 0.05$)]

Discussion

Broodstock domestication is a breeding stock improvement solution that has been successfully applied in numerous countries over many years for penaeid shrimp species such as *P. indicus* (Muthu & Laxminarayana, 1979; Panigrahi, 2018), *P. vannamei* (Andriantahina, Liu, Huang, Xiang, & Yang, 2012; Montaldo, Castillo-Jua´rez, Campos-Montes, & Pe´rez-Enciso, 2012; Zhang, Yu, Li, Xiang, & Liu, 2014), *P. japonicus* (Preston, Brennan, & Crocos, 1999; Hetzel, Crocos, Davis, Moore, & Preston, 2000; Preston, Crocos, Keys, Coman, & Koenig, 2004), and *P. monodon* (Aquacop, 1979; Withyachumnarnkul, Boonsaeng, Flegel, Panyim, & Wongteerasupay, 1998; Coman et al., 2005; Huong et al., 2020; Truc et al., 2021). In reality, breeding stock improvement studies for penaeid shrimp species have focused on improved growth traits, survival rate, disease resistance, and reproductive traits in the offspring (Shengjie, 2020). Following the success of broodstock domestication, it is necessary to evaluate the culturing benefits of domesticated broodstock progeny in different culturing systems to confirm the outstanding potential of domestic breeding stocks for commercial farming.

In aquaculture, growth performance is considered the most crucial commercial trait because improving this trait can increase the number of culturing crops every year by increasing the mean size of individuals over the same culture period. Furthermore, a growth rate increase can also be achieved with other correlated commercial traits, such as feed conversion efficiency and survival rate (Goyard et al., 2002; Caballero - Zamora et al., 2015; Gjedrem & Rye, 2018). Many previous studies have documented the faster growth rate of cultured penaeid shrimp when using sourced breeders from domesticated broodstocks than those from wild broodstocks. Some typical results include selected strains of *P. vannamei* that have faster growth rates of 21 and 23% in raceway and pond farming systems, respectively, after a single generation (Argue et al., 2002). The selection responses for *P. stylirostris* and *P. chinensis* were 21% Field (Goyard et al., 2002) and 18.6% Field (Sui et al., 2016) over five generations.

Moreover, *P. japonicus* showed growth gains of approximately 13% and a 21% increase in the value achieved from the second generation of selected stocks on a commercial farm (Preston et al., 2004). Genetic gains of 10.7% per generation for growth rate were also observed by (Hetzel et al., 2000). In the present study, the growth performance parameters of mean weight and length, daily gains in weight and length, and exceptional growth rates in the weight and length of D-shrimp were significantly higher than those of W-shrimp in both the culturing systems of earthen ponds and composite tanks. The current results agree with previously published data for *P. monodon*. Withyachumnarnkul et al. (1998) recorded that the F1 generation (domesticated *P. monodon* breed stock) grew 10% faster than the parental stock (wild-caught breeders).

Furthermore, Kenway et al. (2006) documented that the bodyweight of a selected *P. monodon* strain was 10% higher than that of the non-selected strain at 30 weeks of age. In Vietnam, Hoa (2009) reported that a daily weight gain of 0.197 g day^{-1} in domesticated *P. monodon* shrimp was significantly higher when compared to non-domesticated shrimp (0.165 g day^{-1}). The mean size of *P. monodon* shrimp was 48.5 ind. kg^{-1} from domesticated stock with a culturing period of 105 days, while it was 50.8 ind. kg^{-1} from non-domesticated stock under the same culturing conditions.

Along with growth performance, the survival rate is a crucial parameter that influences the commercial success of aquaculture Fields(Thitamadee et al., 2016; Gjedrem & Rye, 2018). This factor is closely related to the yield and helps estimate the number of surviving individuals in a pond. This allows farmers to adjust the satisfying daily diet for cultured shrimp, which produces rapidly-growing shrimp while saving feed costs and preventing poor water quality in culturing ponds. Data from the present study showed that the D-shrimp survival rates of 84.3% (pond culture) and 87.59% (tank culture) were significantly higher than those of W-shrimp, which had values of 82.0% and 64.2%, respectively ($p < 0.05$). The results of the present study are consistent with those recorded by Hoa (2009), which showed that after the culturing time of 105 days at a stocking density of 31 ind. m^{-2} in earthen ponds, the survival rate of domesticated *P. monodon* stock (75.75%) was higher than that of non-domesticated stock (72.40%); however, this difference was not significant. Another study of freshwater prawn species (*Macrobrachium rosenbergii*) by Vu, Trong, and Nguyen (2017) found a similar survival rate pattern. The communal testing results of the selected line and its counterparts from the wild in culturing ponds belong to an in-depth study on the effects of selection for fast growth on survival rate during the grow-out phase. The selected line had an 18 % higher survival rate than wild-sourced prawns from the Mekong River ($p < 0.05$). That result suggests that accidental changes in survival occurred during domestication selection.

The feed conversion ratio shows the rate of the amount of food converted into a production unit (1.0 kg weight gain in farmed animals). Growth performance and survival rate are closely related to the feed conversion ratio, biomass, and shrimp yield. In the present study, the feed conversion ratio of 0.98, yield of 3,558 kg ha^{-1} (culture of ponds), and biomass of 470 g m^{-3} (culture of tanks) for D-shrimp were significantly better than those of W-shrimp (132, 2,504 kg ha^{-1} and 101 g m^{-3}, respectively) ($p < 0.05$). The current data were similar to results by Hoa (2009), who found that a feed conversion ratio of 1.47 and a yield of 4.94 tons ha^{-1} of domesticated *P. monodon* shrimp were better than those of non-domesticated shrimp (with values of 1.55 and 4.37 tons ha^{-1}, respectively), despite the insignificant difference in feed conversion ratio between the two cultured shrimp stocks.

In the present study, the D-shrimp stocks of both Huong et al. (2020) and RIA2 achieved a higher culturing efficiency than W-shrimp, even in the pond or tank culture. Moreover, data on the growth performance of tank-cultured shrimp showed that the adverse environmental adaptability of D-shrimp was higher than that of W-shrimp. D-shrimp achieved a daily weight gain of 23 g day^{-1} with a mean final weight of 15.57 g $ind.^{-1}$ and a yield of 470 g m^{-3}, which was 7.7 times, 2.7 times, and 4.7 times higher than that of W-shrimp (0.03 g day^{-1}, 5.7 g $ind.^{-1}$, and 101 g m^{-3}), respectively. Similarly, the daily length gain (0.94 cm day^{-1}) and mean final weight (13.21 cm $ind.^{-1}$) of D-shrimp were 2.2 times and 1.4 times higher than those of W-shrimp (0.42 cm day^{-1} and 9.33 cm ind.$^{-1}$, respectively). This data shows the great potential of using D-shrimp for culture under captive conditions, which limits some elements from natural culturing ponds, such as inorganic nutrients, phytoplankton, and beneficial microorganism components (Avnimelech, 1999; Andriantahina et al., 2012; Vadstein et al., 2018; Anh, Shayo, Nevejan & Hoa, 2021; Anh et al., 2022).

During the culturing period, the water quality parameters of both experiments were controlled within the suitable ranges for *P. monodon* shrimp. Therefore, the data recorded for cultured shrimp was minimally influenced by environmental factors. According to (Pushparajan & Soundarapandian, 2010), the suitable and optimal temperature ranges of *P. monodon* are 23–34 °C and 26–29 °C, respectively, and the appropriate pH range for maintaining good growth performance for this shrimp is 7.5–8.5. Also, a safe TAN level for black tiger shrimp is > 2.0 mg L^{-1} (Charantchakool, 2003). Chen, Liu, and Lei (1990) found that the nitrite value of 3.8 mg L^{-1} is a safe threshold for juvenile black tiger shrimp. The optimal alkalinity range for *P. monodon* is 140.25–176.88 mg L^{-1} (Suwardi & Suwoyo, 2021). In the present study, the documented alkalinity range in the first experiment (146.0–217.1 mg L^{-1}) was slightly higher than the values recorded by Suwardi & Suwoyo (2021) but had no remarkable effect on cultured shrimp, as indicated by the normal molting and development of shrimp during the culturing period.

Conclusion

The present study indicated that D-shrimp achieved a significantly higher commercial benefit in terms of growth performance, survival rate, feed conversion ratio, and yield or biomass of harvest when compared to W-shrimp, even in natural conditions of pond culture and captive conditions of tank culture. In particular, with in-tank culturing conditions, D-shrimp's culturing advantages in growth, survival rate, and biomass were many times higher than those of W-shrimp. It is recommended that D-shrimp should be commonly used for grow-out culture in practice. Notably, studies that enhance the efficiency of sourced *P. monodon* breeding stocks from domesticated broodstock in different captive culture models for commercial purposes must be conducted in the future.

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