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Comparative study on direct stocking versus nursery rearing in *Litopenaeus vannamei* culture systems

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ABSTRACT

We conducted a comparative study to evaluate the growth performance, survival, feed utilization, and biomass production of *Litopenaeus vannamei* under two stocking strategies: direct stocking (T₁) and nursery rearing (T₂) with a 25-day nursery phase. The experiment used a completely randomized design with two treatments and three replicates each. Stocking density was standardized at 35 PL/m² for both treatments during the grow-out phase (100-120 days). Nursery-reared shrimp (T₂) showed significantly better performance: final harvest weight (21.85 ± 1.52 g vs. 18.05 ± 1.45 g, 21.1% higher), daily growth rate (0.273 ± 0.019 g/day vs. 0.225 ± 0.018 g/day, 21.3% higher), specific growth rate (8.92 ± 0.35 %/day vs. 8.15 ± 0.32 %/day, 9.4% higher), and feed conversion ratio (1.42 ± 0.06 vs. 1.72 ± 0.08, 17.4% better). Grow-out survival was significantly higher in T₂ (80.7 ± 1.5% vs. 59.0 ± 2.0%, *p* < 0.001), and overall survival from post-larvae to harvest was 67.8% in T₂ vs. 59.0% in T₁. Biomass yield increased by 65.4% in T₂ (6,168 kg/ha vs. 3,728 kg/ha). Coefficient of variation was significantly lower in T₂ (15.2 ± 1.6% vs. 22.8 ± 2.1%), indicating better size uniformity. Water quality parameters showed no significant differences between treatments during grow-out (*p* > 0.05), confirming that performance differences were due to stocking strategy. We conclude that nursery rearing significantly improves growth, survival, feed efficiency, size uniformity, and biomass production in *L. vannamei* culture compared to direct stocking.

Keywords: Nursery rearing, Direct stocking, *Litopenaeus vannamei*, Growth performance, Survival, Feed conversion ratio

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Introduction

The global aquaculture industry has emerged as the fastest-growing animal food-producing industry in the last five decades, with farmed aquatic products exceeding capture fisheries as the latter has plateaued (FAO, 2022) [1]. This growth is attributed to population pressure, rising seafood demand, technological advancements, and overexploitation of fish resources. In this industry, penaeid shrimp farming has assumed exceptional economic importance as one of the most valuable globally traded aquaculture products. Its rapid expansion in tropical and subtropical coastal areas has profoundly affected rural economies, creating millions of jobs, especially in developing countries where it forms the backbone of blue economy projects (Raju *et al.*, 2021; CIBA, 2020) [3, 2].

Of the farmed penaeid shrimp, the Pacific white shrimp (*Litopenaeus vannamei*) is the most cultivated due to its desirable biological traits. It grows very fast, reaching marketable size much sooner than other species (Wyban *et al.*, 1991) [4]. Its extraordinary euryhaline tolerance allows it to thrive in a wide range of salinity levels, from almost freshwater to hypersaline conditions (Lavens *et al.*, 1996) [5]. The species also has high fecundity and tolerance of different production systems, from low-intensity extensive ponds to hyper-intensive biofloc systems (Wyban *et al.*, 1991; Lavens *et al.*, 1996) [4, 5].

In India, shrimp farming has emerged as a significant sector along both coasts, with export earnings and production increasing considerably after the development of pathogen-free strains (CIBA, 2020) [2]. According to Raju *et al.* (2021) [3], the sector has created millions of jobs in coastal areas, with substantial effects on women's employment in hatcheries and processing units.

However, increased focus on shrimp farming has also accentuated biological, environmental, and economic risks. These issues are particularly pronounced at early life stages, where post-larvae and juveniles are highly sensitive to environmental changes, nutritional imbalances, and disease. Lightner (2011) [6] reported catastrophic effects of viral diseases in the Western Hemisphere, where mortality outbreaks can decimate entire crops. Flegel (2012) [7] reviewed pathogen emergence in Asia, where production intensification has in

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creased disease transmission efficiency, especially due to bacterial pathogens like *Vibrio parahaemolyticus* (causing Early Mortality Syndrome) and viruses like White Spot Syndrome Virus.

The transition from controlled hatchery conditions to variable grow-out conditions is a key stress point in shrimp culture. In hatcheries, factors like temperature, salinity, and water quality are held within tight optimal limits. When shrimp are moved to grow-out ponds, they face environmental variability, competition, predation, and new microbial communities. Boyd *et al.* (2015) [8] quantified pond variability, including daily changes in dissolved oxygen, pH, and temperature. Similar patterns of early-life management improving later performance have been documented in other aquaculture systems (Dar *et al.*, 2022; Ratnakar *et al.*, 2024) [9, 10].

The optimization of production has focused on two strategic methods: direct stocking and nursery rearing. Direct stocking involves transferring post-larvae directly from hatcheries to final grow-out ponds without an intermediate step. This method was common in early shrimp culture when production intensity was low (Hopkins *et al.*, 1993) [11]. Its advantages include simplicity and lower capital costs. However, direct stocking subjects post-larvae to drastic environmental changes, causing physiological stress and mortality risk. Lightner (2011) [6] explained how stress triggers neuroendocrine pathways that mobilize energy stores and modulate immune responses. Flegel (2012) [7] reported Early Mortality Syndrome causing > 70% mortality within weeks of direct stocking.

In contrast, nursery rearing is an advanced management technique that mitigates hazards associated with early pond access. This sequential approach involves stocking post-larvae in nursery conditions for 15-30 days, then transferring larger, stronger juveniles to grow-out ponds. The effectiveness of nursery rearing was proven by Wasielesky *et al.* (2006) [12]. Nursery systems provide environmental control, optimized feeding, and health management (Jory *et al.*, 2020; Samocha *et al.*, 2022) [13, 14]. Benefits include gradual acclimation to salinity and temperature, optimized feeding schedules, intensive water quality management, and immune system conditioning through controlled microbial exposure (Crab *et al.*, 2012; Wasielesky *et al.*, 2013) [15, 16].

Given this background, we designed this study to compare direct stocking versus nursery rearing in *Litopenaeus vannamei* culture systems.

Materials and Methods

Study location and duration

The experiment was conducted at an aquaculture research facility in a coastal area of India with filtered seawater supply, bore well freshwater source, hatchery facility, nursery tanks, and earthen grow-out ponds. The study lasted 100-120 days, comprising a 25-day nursery stage (only T₂) and a 75-90 day grow-out stage (both treatments).

Experimental design

We used a completely randomized design (CRD) with two treatments and three replicates each.

Table 1.1. Experimental treatments

Treatment	Description	Replicates
T ₁ – Direct Stocking	PL ₁₂ –PL ₁₅ stocked directly into grow-out ponds without intermediate rearing	3
T ₂ – Nursery Rearing	PL ₁₂ –PL ₁₅ reared for 25 days in nursery tanks before transfer to grow-out ponds	3

Table 2.2. Nursery phase units

Tank type	Fiber-reinforced plastic (FRP) circular tanks
Capacity	5 m ³
Working volume	4 m ³
Water depth	0.8 m
Aeration	Continuous via air stones (DO > 5 mg/L)
Drainage	Central drainage system
Water source	Filtered (5 µm) and UV-treated seawater

Table 1.3. Grow-out phase units

Pond type	Earthen ponds
Pond area	0.1 ha (1000 m ²) each
Water depth	Maintained at 1.2 m throughout culture period
Water supply	Independent inlet and outlet for each pond
Aeration	Two 2-hp paddlewheel aerators per pond
Water exchange	5-10% daily as needed

Stocking density

Table 1.4. Stocking density

Phase	T ₁ (Direct Stocking)	T ₂ (Nursery Rearing)
Nursery phase	Not applicable	1500 PL m ⁻³ (6,000 PL per tank)
Grow-out phase	35 PL m ⁻²	35 PL m ⁻²

Nursery phase protocol (T₂ only)

Stocking density: 1500 PL/m³ (6,000 PL per tank in 4 m³ working volume). Water quality was monitored daily for temperature (28-30 °C), DO (> 5 mg/L), pH (7.8-8.2), salinity (25 ± 2 ppt), TAN (< 1.0 mg/L), nitrite (< 0.5 mg/L), nitrate (< 10 mg/L), and alkalinity (> 100 mg/L). Feeding used commercial nursery crumble feed (45% protein) four times daily, starting at 25% of biomass daily and reducing to 15% by the end. Weekly sampling monitored growth.

Grow-out phase protocol (both treatments)

Ponds were prepared by drying (7-10 days), liming, fertilization, water filling to 1.2 m, and aeration installation. Both treatments were stocked at 35 PL/m². Water quality was monitored twice daily for temperature and DO, and weekly for TAN, nitrite, and transparency. Feeding used starter crumble (40% protein, 3 times daily) for weeks

1-4, grower pellet (35% protein) for weeks 5-8, and finisher pellet (32% protein) for weeks 9-harvest. Weekly sampling monitored growth.

Growth parameters

We calculated:

- Mean body weight = $\frac{\sum \text{individual weights}}{n}$
- Weight gain = Final weight – Initial weight
- Daily growth rate (DGR) = $\frac{\text{Final weight} - \text{Initial weight}}{\text{Culture days}}$
- Specific growth rate (SGR) = $\left[\frac{\ln \text{Final weight} - \ln \text{Initial weight}}{\text{Days}} \right] \times 100$
- Feed conversion ratio (FCR) = $\frac{\text{Total feed given}}{\text{Total biomass gain}}$
- Size uniformity (CV) = $\frac{\text{Standard deviation}}{\text{Mean weight}} \times 100$
- Survival (%) = $\frac{\text{Final count}}{\text{Initial count}} \times 100$

Statistical analysis

Data were analyzed using independent *t*-test for growth parameters and survival, repeated measures ANOVA for growth trajectories, and paired *t*-test for within-treatment survival. Normality was tested using Shapiro-Wilk test ($p > 0.05$). Homogeneity of variance was tested using

Levene's test ($p > 0.05$). Significance was set at $\alpha = 0.05$. Effect size was calculated using Cohen's *d*.

Results

Water quality parameters

All water quality parameters were maintained within acceptable ranges throughout the study.

Table 1.5. Nursery phase water quality

Parameter	Mean $\pm$ SD	Range	Optimal Range
Temperature (°C)	28.6 $\pm$ 0.4	28.0–29.2	28–30
Dissolved oxygen (mg/L)	5.8 $\pm$ 0.3	5.4–6.3	> 5.0
pH	8.0 $\pm$ 0.1	7.9–8.2	7.8–8.2
Salinity (ppt)	25.2 $\pm$ 0.8	24.5–26.0	25 $\pm$ 2
TAN (mg/L)	0.42 $\pm$ 0.15	0.20–0.65	< 1.0
Nitrite-N (mg/L)	0.18 $\pm$ 0.08	0.10–0.30	< 0.5
Nitrate-N (mg/L)	4.2 $\pm$ 1.1	3.0–6.0	< 10.0
Alkalinity (mg/L CaCO ₃)	135 $\pm$ 12	120–155	> 100

No significant differences were found for any water quality parameter between treatments during grow-out ($p > 0.05$). Therefore, differences in growth and survival can be attributed to stocking strategy, not environmental variation.

Table 1.6. Grow-out phase water quality

Parameter	T ₁ (Direct Stocking)	T ₂ (Nursery Rearing)	<i>p</i> -value	Significance
Temperature (°C)	28.9 $\pm$ 1.2	29.0 $\pm$ 1.1	0.842	NS
Dissolved oxygen (mg/L) – Dawn	4.2 $\pm$ 0.5	4.3 $\pm$ 0.4	0.765	NS
Dissolved oxygen (mg/L) – Dusk	5.8 $\pm$ 0.6	5.9 $\pm$ 0.5	0.801	NS
pH	7.9 $\pm$ 0.2	8.0 $\pm$ 0.2	0.693	NS
Salinity (ppt)	24.8 $\pm$ 1.5	24.9 $\pm$ 1.4	0.914	NS
TAN (mg/L)	0.58 $\pm$ 0.20	0.52 $\pm$ 0.18	0.622	NS
Nitrite-N (mg/L)	0.22 $\pm$ 0.10	0.19 $\pm$ 0.09	0.571	NS
Transparency (cm)	35.2 $\pm$ 4.1	34.8 $\pm$ 3.9	0.879	NS

Nursery phase performance (T₂ only)

Table 1.7. Growth performance during 25-day nursery phase

Parameter	Value
Initial weight (g)	0.012 $\pm$ 0.002
Final weight at transfer (g)	0.85 $\pm$ 0.12
Weight gain (g)	0.838 $\pm$ 0.12
Daily growth rate (g/day)	0.0335 $\pm$ 0.005
Specific growth rate (%/day)	17.2 $\pm$ 1.8

Growth performance

At stocking (Week 0), T₂ shrimp were already 0.85 g while T₁ shrimp were only 0.012 g—a massive 70-fold difference. At Week 1, T₂ shrimp were 1.92 g vs. 0.85 g for T₁ (125.9% difference). This initial advantage gradually decreased over time but never disappeared. By harvest (Week 11), T₂ shrimp were 21.85 g vs. 18.05 g for T₁—still 21.1% heavier. The parallel growth trajectories (both treatments grew at similar rates after Week 4) indicate that the nursery advantage is established early and maintained throughout the culture period. The head start from nursery rearing never gets fully erased.

Table 1.8. Weekly growth trajectory

Week	T ₁ Mean Weight (g)	T ₂ Mean Weight (g)	Difference (%)
0 (Stocking)	0.012 $\pm$ 0.002	0.85 $\pm$ 0.12	-
1	0.85 $\pm$ 0.15	1.92 $\pm$ 0.22	125.90%
2	2.34 $\pm$ 0.28	3.85 $\pm$ 0.35	64.50%
3	4.12 $\pm$ 0.42	5.98 $\pm$ 0.48	45.10%
4	6.05 $\pm$ 0.55	8.12 $\pm$ 0.62	34.20%
5	7.98 $\pm$ 0.68	10.25 $\pm$ 0.75	28.40%
6	9.85 $\pm$ 0.82	12.38 $\pm$ 0.88	25.70%
7	11.62 $\pm$ 0.95	14.42 $\pm$ 1.02	24.10%
8	13.35 $\pm$ 1.08	16.38 $\pm$ 1.15	22.70%
9	15.02 $\pm$ 1.20	18.25 $\pm$ 1.28	21.50%
10	16.58 $\pm$ 1.32	20.05 $\pm$ 1.40	20.90%
11 (Harvest)	18.05 $\pm$ 1.45	21.85 $\pm$ 1.52	21.10%

This is the most important table in the study. It directly compares the two treatments across all key performance metrics. The *p*-values (all < 0.05) confirm that all differences are statistically significant, meaning they are real effects, not random variation. Final harvest weight (*p*

= 0.012): T_2 shrimp were 3.8 g heavier (21.85 vs. 18.05 g). In commercial shrimp farming, this 21% increase in size translates directly to higher prices per kilogram and greater profitability. FCR ($p = 0.003$): T_2 achieved FCR of 1.42 vs. 1.72 for T_1 . This 17.4% improvement means nursery-reared shrimp converted feed into body weight much more efficiently. Since feed is the largest operational cost in

shrimp farming (typically 50-60% of total costs), this improvement has major economic implications. CV ($p = 0.002$): The coefficient of variation was 33.3% lower in T_2 (15.2% vs. 22.8%). This means nursery-reared shrimp were much more uniform in size. Uniform size is critical for processing—processors pay premium prices for uniformly sized shrimp and give discounts for mixed sizes.

Table 1.9. Comparative growth performance

Parameter	T_1 (Direct Stocking)	T_2 (Nursery Rearing)	Improvement (%)	p -value
Initial weight (g)	0.012 ± 0.002	0.012 ± 0.002	-	NS
Weight at transfer (g)	-	0.85 ± 0.12	-	-
Final harvest weight (g)	18.05 ± 1.45	21.85 ± 1.52	21.10%	0.012
Total weight gain (g)	18.038 ± 1.45	21.838 ± 1.52	21.10%	0.012
Daily growth rate (g/day)	0.225 ± 0.018	0.273 ± 0.019	21.30%	0.008
Specific growth rate (%/day)	8.15 ± 0.32	8.92 ± 0.35	9.40%	0.015
Feed conversion ratio (FCR)	1.72 ± 0.08	1.42 ± 0.06	-17.40%	0.003
Coefficient of variation (CV %)	22.8 ± 2.1	15.2 ± 1.6	-33.30%	0.002

Survival rates

Grow-out survival in T_2 averaged 80.7% compared to only 59.0% in T_1 . That is an absolute increase of 21.7 percentage points. In practical terms, for every 100 shrimp stocked, T_2 harvested 81 shrimp while T_1 harvested only 59 shrimp—a difference of 22 more shrimp per 100 stocked. The consistency across replicates (79-82% for T_2 , 57-61%

for T_1) confirms that this is a robust effect, not due to chance. Why does nursery rearing improve survival? Because larger, stronger juveniles are better able to handle the stress of pond transfer, compete for food, and resist diseases. The low standard deviations (1.5% for T_2 , 2.0% for T_1) indicate consistent management across all ponds.

Table 1.10. Grow-out survival

Treatment	Replicate	Stocked (n)	Harvested (n)	Survival (%)
T_1 (Direct)	1	35,000	20,650	59
	2	35,000	19,950	57
	3	35,000	21,350	61
	Mean ± SD	35,000	20,650 ± 700	59.0 ± 2.0
T_2 (Nursery)	1	35,000*	28,350	81
	2	35,000*	27,650	79
	3	35,000*	28,700	82
	Mean ± SD	35,000	28,233 ± 525	80.7 ± 1.5

Biomass production and feed efficiency

Biomass yield in T_2 was 6,168 kg/ha compared to only 3,728 kg/ha in T_1 —a 65.4% increase. This is the bottom line for farmers: nursery rearing produced 2,440 kg more shrimp per hectare. This increase comes from two sources: higher survival (36.8% improvement) and larger individual shrimp (21.1% improvement). The multiplicative effect of these two factors ($1.368 \times 1.211 = 1.654$) explains the 65.4% increase. No other management intervention in shrimp farming typically achieves such a large production increase.

Statistical summary

The t -values are all well above the critical value (approximately 2.78 for $df = 4$ at $\alpha = 0.05$). The highest t -value (8.45 for grow-out survival) indicates an extremely strong treatment effect. The negative t -values for FCR and CV simply indicate that T_2 had lower (better) values than T_1 . These results confirm that the observed differences are real, not due to random variation or chance.

Table 4.11. Biomass production

Parameter	T_1 (Direct)	T_2 (Nursery)	Improvement
Mean harvest weight (g)	18.05	21.85	21.10%
Survival (%)	59	80.7	36.80%
Stocking density (m^{-2})	35	35	-
Biomass yield (kg/ha)	3,728	6,168	65.40%

Discussion

Our study demonstrated that nursery rearing significantly improves growth, survival, feed efficiency, size uniformity, and biomass production in *Litopenaeus vannamei* compared to direct stocking. These

results are consistent with Wasielesky *et al.* (2006) [12], who first proved the effectiveness of nursery rearing over direct stocking.

Growth performance: Nursery-reared shrimp (T_2) showed 21.1% higher final harvest weight (21.85 g vs. 18.05 g) and 21.3% higher daily growth rate. This improvement can be attributed to several factors. First, nursery systems enable gradual acclimation to desired

salinity and temperature conditions, reducing osmoregulatory stress (Lavens *et al.*, 1996) [5]. Second, optimized feeding schedules in nurseries promote fast, simultaneous growth, ensuring all individuals receive sufficient nutrients (Jory *et al.*, 2020) [13]. Third, reduced metabolic stress allows shrimp to allocate more resources to growth

rather than stress response (Lightner, 2011) [6]. Similar patterns of early-life management improving later performance have been documented in other aquaculture systems (Dar *et al.*, 2022; Ratnakar *et al.*, 2024) [9, 10].

Table 4.12. Independent *t*-test Results for Key Parameters

Parameter	<i>t</i> -value	df	<i>p</i> -value	Significance
Final harvest weight	3.85	4	0.012	Significant
Daily growth rate	4.22	4	0.008	Significant
Specific growth rate	3.62	4	0.015	Significant
Feed conversion ratio	-5.18	4	0.003	Significant
Coefficient of variation	-5.42	4	0.002	Significant
Grow-out survival	8.45	4	< 0.001	Significant
Overall survival	5.12	4	0.004	Significant

Feed conversion ratio: FCR was significantly lower in T₂ (1.42 vs. 1.72, 17.4% improvement). This indicates better feed efficiency in nursery-reared shrimp. Improved FCR results from better nutrient utilization, reduced stress, and more uniform feeding behavior. Brown, Boyd, and Chappell (2009) [17] showed that although nursery infrastructure requires investment, enhanced survival, growth, and FCR compensate for the expenditure.

Survival: Grow-out survival was 80.7% in T₂ vs. 59.0% in T₁ (*p* < 0.001). This 21.7 percentage point increase is substantial. Higher survival in nursery-reared shrimp can be attributed to larger initial size, better physiological condition, and enhanced immune competence at transfer. Lightner (2011) [6] explained how stress-induced immunosuppression predisposes shrimp to opportunistic pathogens. Flegel (2012) [7] reported that Early Mortality Syndrome causes > 70% mortality within weeks of direct stocking. Nursery systems facilitate immune system conditioning through controlled microbial exposure (Crab *et al.*, 2012; Wasielesky *et al.*, 2013) [15, 16].

Size uniformity: CV was significantly lower in T₂ (15.2% vs. 22.8%, 33.3% improvement). Montoya *et al.* (2006) [18] found that nursery-reared shrimp produced highly uniform groups because all individuals had unlimited access to feed in a low-competition environment. This uniformity persists through grow-out, as equal competitors grow in synchrony. Brito, Vinatea, and Wasielesky (2016, 2020) also found that nursery-reared *L. vannamei* in biofloc systems consistently had better size uniformity.

Biomass production: Biomass yield increased by 65.4% in T₂ (6,168 kg/ha vs. 3,728 kg/ha). This increase results from combined effects of higher survival (36.8% improvement) and higher harvest weight (21.1% improvement). Kumar *et al.* (2018) [19] showed similar benefits of 20-25 day nursery phases in Indian semi-intensive systems. The 25-day nursery phase increased total production cycle by 25 days but reduced grow-out phase by 5 days (75 days instead of 80 days). This shorter grow-out period, combined with higher survival and growth, may allow an additional crop per year in tropical regions (Raju *et al.*, 2021) [20].

Water quality: No significant differences were found between treatments for any water quality parameter during grow-out (*p* > 0.05). This confirms that performance differences were due to stocking strategy, not environmental variation. Boyd *et al.* (2015) [8] quantified pond variability and emphasized the importance of standardized conditions for valid comparisons.

Economic implications: The 65.4% increase in biomass yield, 17.4% improvement in FCR, and 21.7% increase in survival all contribute to improved profitability. Although nursery infrastructure requires capital investment, enhanced production efficiency compensates for the expenditure (Brown, Boyd, & Chappell, 2009; Wasielesky *et al.*, 2006) [17, 12]. Shorter production cycles may allow additional crops per year, further improving economic returns (Raju *et al.*, 2021) [20].

Conclusion

This 100-120 day comparative study proved that nursery rearing significantly improves growth performance, survival, feed utilization, size uniformity, and biomass production of *Litopenaeus vannamei* compared to direct stocking. Nursery-reared shrimp (T₂) showed 21.1% higher final harvest weight (21.85 g vs. 18.05 g), 21.3% higher daily growth rate, 17.4% better feed conversion ratio (1.42 vs. 1.72), 33.3% better size uniformity (CV 15.2% vs. 22.8%), 36.8% higher grow-out survival (80.7% vs. 59.0%), and 65.4% higher biomass yield (6,168 kg/ha vs. 3,728 kg/ha) compared to directly stocked shrimp (T₁). Overall survival from post-larvae to harvest was 67.8% in T₂ vs. 59.0% in T₁. Water quality parameters showed no significant differences between treatments during grow-out (*p* > 0.05), confirming that performance differences were due to stocking strategy, not environmental variation. The 25-day nursery phase added 25 days to the total production cycle but reduced grow-out phase by 5 days. All effect sizes were classified as "large" (Cohen's *d* > 0.8). We conclude that nursery rearing is a superior stocking strategy for *L. vannamei* culture, offering significant biological and production advantages over direct stocking.

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