International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 10 No. 3s, 2024
https://theaspd.com/index.php

Effects of Stocking Density on Growth Performance of *Litopenaeus Vannamei* Under Low and High Salinity Pond Culture During the Second Crop Of 2019 in Andhra Pradesh, India

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ABSTRACT
This study conducted an independent aquaculture experiment focused on Litopenaeus vannamei farmed in the second crop of 2019 in Krishna District, Andhra Pradesh, India. The core objective of the research was to assess the growth rate of the shrimp under different stocking densities in low-salinity and high-salinity ponds. This study set up in four different types of water quality conditions like low-salinity low-density, low-salinity high-density, high-salinity low-density and high-salinity high-density. The average measured values of five core water quality indicators, namely pH, salinity, dissolved oxygen, ammonia nitrogen, and temperature, were collected for all four groups of ponds. The study ultimately derived the core conclusion that stocking density is negatively correlated with the shrimp's growth performance. It clarifies that low stocking density is more conducive to the growth and production of the shrimp, while high stocking density reduces production efficiency. The findings of this study hold important guiding significance for the sustainable farming of Litopenaeus vannamei under different salinity conditions.
Keywords: *Litopenaeus vannamei; stocking density; salinity; growth performance; shrimp culture; aquaculture.*

INTRODUCTION

As a core industry that supports global food security and the sustainable development of the global fishery economy, global aquaculture has seen continuous scale expansion in recent years (Blanchardet al., 2017; FAO, 2022; Boyd et al., 2022). Among its subsectors, shrimp farming has become a key part of the global aquatic economy, driven by growing international market demand and the rapid popularization of intensive farming models (Naylor et al., 2021; Jolly et al., 2023; Ababouch et al., 2023). Among all mainstream farmed shrimp species, the Pacific white shrimp, *Litopenaeus vannamei*, has become the world's most widely farmed shrimp species, thanks to its core strengths of fast growth, high farming survival rate, strong environmental adaptability, and a wide tolerance range for salinity (Wyban & Sweeney, 1991; Boyd & Clay, 2002; Awaad, 2023). After this species was introduced to India, its farming scale expanded rapidly in Andhra Pradesh, India's core shrimp production region, and it has grown into a core pillar category of local aquaculture (Kumaran et al., 2017).

Based on a review of authoritative research literature in the field that covers both classic findings and cutting-edge advances spanning 1991 to 2023, the core factors that restrict the productivity and sustainability of *Litopenaeus vannamei* farming can be divided into three categories (Anand et al., 2023; Jaffer et al., 2021). First, stocking density, the core management factor: excessively high density will trigger competition for feed and space among shrimp groups and induce stress responses, which in turn lead to problems such as slowed growth, deteriorated water quality, and accumulation of ammonia nitrogen and nitrite (Moss & Moss, 2004; Hargreaves, 1998). Reasonable low stocking density can effectively avoid these risks (Anand et al., 2023). Second, general water quality parameters including dissolved oxygen, pH, temperature, and ammonia nitrogen: these parameters directly affect the physiological state and growth efficiency of shrimp, and continuous water quality monitoring is a core requirement to guarantee sustainable farming (Boyd & Tucker, 1998; Chien, 1992). Third, salinity, a species-specific influencing factor: the euryhalinity of *Litopenaeus vannamei* supports its farming across diverse scenarios, including high-salt coastal ponds and low-salt inland ponds (Saoud et al., 2003). However, salinity fluctuations will disrupt its osmoregulation mechanism, increase physiological energy consumption, and inhibit growth, while maintaining optimal salinity can improve feed utilization rate and growth efficiency (Ponce-Palafox et al., 1997; Jaffer et al., 2021).

This sorting process that narrows down layer by layer from broad to specific establishes a clear research context for the exploration of the specific issues of this study. Krishna District, Andhra Pradesh, India is a core aquaculture region in the country. The area's primary cultured species is *Litopenaeus vannamei* (Pacific white shrimp), and local farmers operate two types of aquaculture ponds: high-salinity and low-salinity. Farmers set the stocking density of juvenile shrimp based on a combination of pond conditions, water resource availability, and economic factors. Currently, there is a lack of data on the combined effect of stocking density and salinity on the growth performance of the second-season crop of *Litopenaeus vannamei*. To address this gap, our research team conducted a study in this production region during the second growing season of 2019, to assess the impact of stocking density on the growth performance of *Litopenaeus vannamei* in the two categories of salinity ponds.

MATERIAL AND METHODS

Experiments were conducted for the estimation of growth parameters in low- and high-salinity ponds under low and high stocking densities. Ponds were initially prepared through drying, tilling to remove pests and predators and to oxidize the bottom soil, followed by liming to correct soil pH (Boyd & Tucker, 1998). Natural food organisms in the ponds were enriched by following Good Management Practices (GMPs) adopted in shrimp aquaculture systems (FAO, 2022). Sampling for estimating the average body weight of shrimps from the culture ponds was initiated from the 50th day of the culture period and continued until harvesting. Weekly growth performance in all experimental ponds was recorded throughout the culture period. The physical condition and health status of shrimp were also monitored during sampling procedures (Fast & Lester, 1992).

Feeding was provided according to the estimated feed chart, considering shrimp growth performance and estimated survival rate in the ponds (Wyban & Sweeney, 1991). Water temperature was measured directly in the field using a mercury thermometer with a range of 0° to 100°C and a least count of 1°C. The pH of pond water was measured using an "ELICO" pH meter. Dissolved oxygen analysis was carried out by collecting water samples in BOD bottles, fixing the samples on-site, and subsequently analyzing them in the laboratory using Winkler's titration method (APHA, 2017). Salinity and ammonia concentrations were estimated following the procedure described by Grasshoff et al. (1999).

Feed conversion ratio (FCR) and average daily growth (ADG) were calculated using the following formulae:

FCR = Total weight of harvested shrimps/Total feed used

ADG = Total weight gained by shrimps/Total days of culture

RESULTS AND DISCUSSION

In Krishna District, the average weekly growth ranged from 1.90 g to 1.94 g in low-stocking ponds of low-salinity waters during the second crop of 2019, whereas it ranged from 1.40 g to 1.66 g in high-stocking ponds of low-salinity waters during the same culture period (Table 1). In the second crop during 2019, low-salinity and low-stocking-density ponds of Krishna District recorded average values of pH 8.0, salinity 4 ppt, dissolved oxygen 5.2 ppm, ammonia 0.54 ppm, and temperature 28.93°C. The average weekly growth observed under these conditions was 1.91 g at a stocking density of 20 shrimp m^2. In low-salinity and high-stocking-density ponds during the second crop of 2019, the average pH, salinity, dissolved oxygen, ammonia, and temperature values were 8.31, 4 ppt, 4.95 ppm, 0.90 ppm, and 29.08°C, respectively. The average weekly growth recorded under these conditions was 1.54 g at a stocking density of 45 shrimp m^2.

In Krishna District, the average weekly growth ranged from 2.14 g to 2.30 g in low-stocking ponds of high-salinity waters during the second crop of 2019, whereas the growth ranged from 1.90 g to 2.00 g in high-stocking ponds of high-salinity waters. In the second crop during 2019, high-salinity and low-stocking-density ponds recorded average values of pH 8.34, salinity 20 ppt, dissolved oxygen 4.85 ppm, ammonia 0.60 ppm, and temperature 29.05°C. The average weekly growth observed under these conditions was 2.24 g at a stocking density of 20 shrimp m^2. In high-salinity and high-stocking-density ponds during the second crop of 2019, the average values of pH, salinity, dissolved oxygen, ammonia, and temperature were 8.20, 20 ppt, 4.96 ppm, 0.90 ppm, and 29.05°C, respectively. The average weekly growth recorded under these conditions was 1.97 g at a stocking density of 50 shrimp m^2. The recorded growth values indicated that low stocking densities produced higher average weekly growth rates compared to high stocking densities under both low- and high-salinity conditions.

Maintaining optimum water quality parameters in culture ponds is essential for the growth and survival of shrimp larvae, as excess feed, metabolic wastes, and nitrogenous compounds can deteriorate water quality and negatively affect shrimp health and production performance (Soundarapandian & Gunalan, 2008).Gunalan et al. (2010) reported good growth and survival of *Litopenaeus vannamei* in brackish water ponds with salinity levels ranging from 10 to 35 ppt, which are considered suitable conditions for shrimp culture. However, *L. vannamei* is also capable of tolerating salinity as low as 2.45 ppt (Parker et al., 1974). Praveen Kumar and Krishna (2015) reported maximum average daily growth at a salinity of 9.89 ppt while maintaining salinity levels between 6.5 and 12.5 ppt. In the present study, maximum average weekly growth was recorded at 20 ppt salinity.

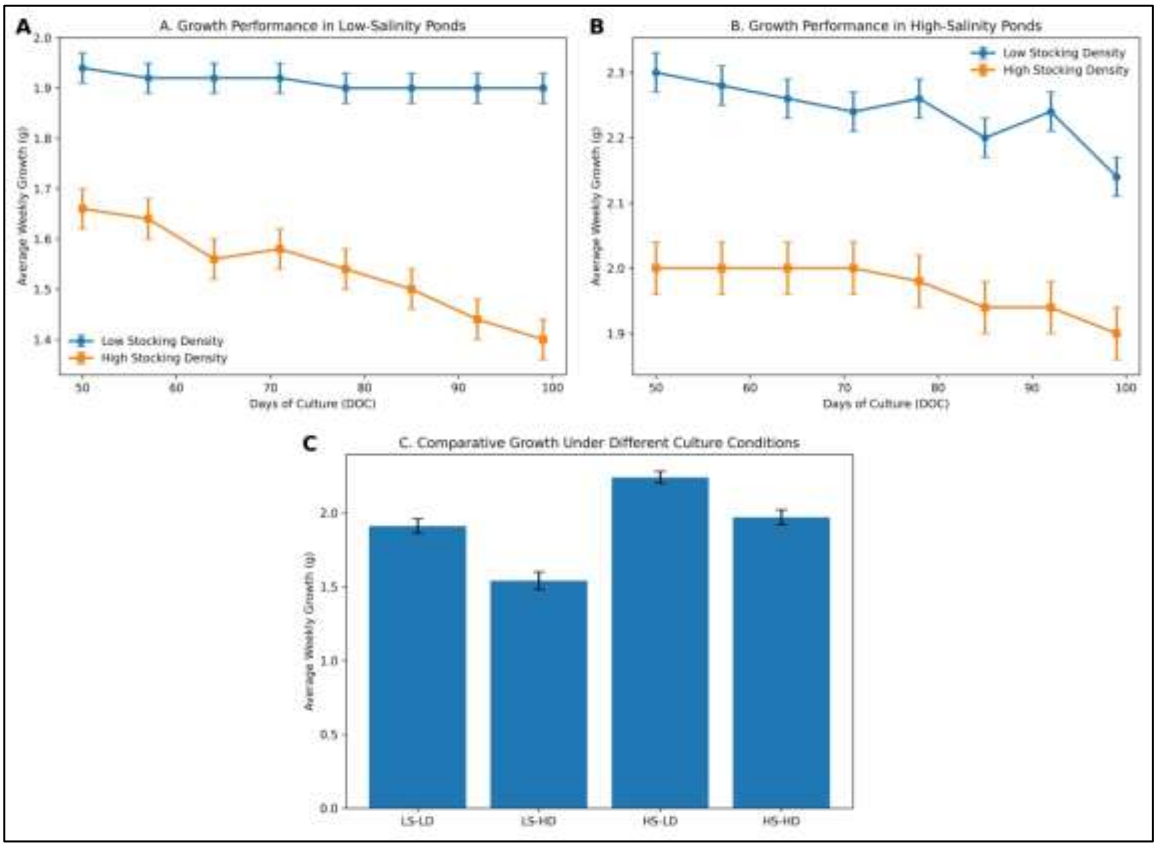

Figure 1.

(A) Growth performance of *Litopenaeus vannamei* cultured under low-salinity pond conditions at low and high stocking densities during the second crop of 2019 in Krishna District, Andhra Pradesh, India.

(B) (B) Growth performance of *Litopenaeus vannamei* cultured under high-salinity pond conditions at low and high stocking densities during the second crop of 2019.

(C) (C) Comparative average weekly growth performance of *Litopenaeus vannamei* under different salinity and stocking density conditions. Error bars represent standard deviation (SD).

Wang et al. (2004) reported that the favourable pH range for *L. vannamei* culture is between 7.6 and 8.6. Praveen Kumar and Krishna (2015) observed pH values ranging from 7.2 ± 0.4 to 7.9 ± 0.3 under different stocking densities. In the present study, the suitable pH for maximum average daily growth was 8.07. Praveen Kumar and Krishna (2015) also reported dissolved oxygen levels ranging from 4.6 ± 1.76 to 6.21 ± 1.25 ppm in ponds with different stocking densities. In the present study, the optimal dissolved oxygen concentration for better growth and survival was 5.53 ppm. Similarly, Praveen Kumar and Krishna (2015) reported average temperatures ranging from 35.9 ± 2.6°C to 36.5 ± 2.2°C, whereas the present study observed an optimal temperature of 32.3°C for better growth and survival. Average ammonia concentrations ranging from 0.22 to 1.8 mg L^{-1}. In the present study, the ideal ammonia concentration for better growth and survival was 0.61 ppm (Suriya et al., 2016; Indriani et al., 2024). The recorded growth values clearly indicated that higher average weekly growth rates were observed under low stocking densities, whereas reduced growth rates were recorded under high stocking densities. Similar findings were previously reported by Suriya et al. (2016) and Parvathi and Padmavathi (2018).

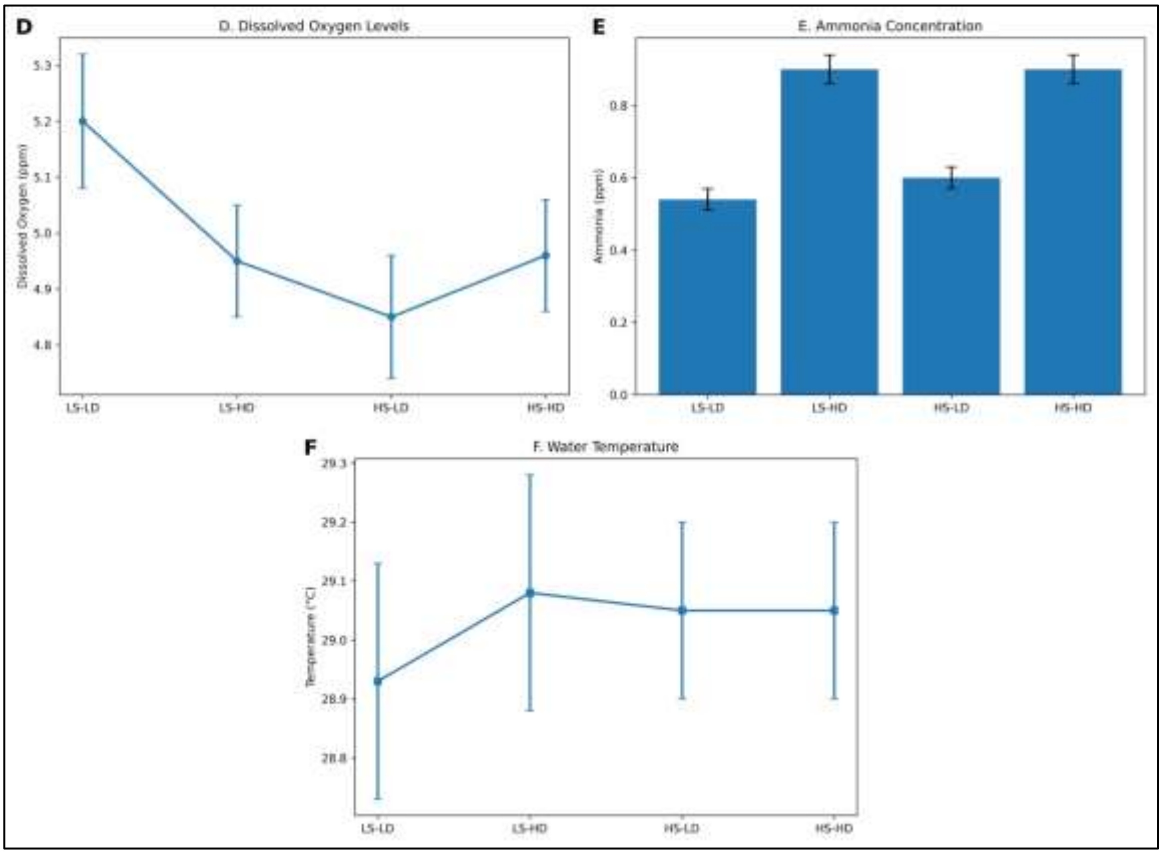

Figure 2.

(D) Dissolved oxygen concentrations recorded in experimental ponds under different salinity and stocking density conditions during the second crop of 2019.
(E) Ammonia concentrations observed in experimental ponds under varying salinity and stocking density conditions.
(F) Water temperature recorded in experimental ponds during the culture period. Error bars represent standard deviation (SD).

CONCLUSION

Thisstudy carried out field farming experiments of white leg shrimp (*Litopenaeus vannamei*) in Krishna District, Andhra Pradesh, India, during the second crop in 2019. We set up a total of 4 groups of parallel control experimental conditions, which paired low and high-salinity ponds with low and high farming densities. The study explicitly verified that farming density has a significant core impact on the growth performance of *L. vannamei*, and sorted out the shrimp's growth differences under different combinations of salinity and farming density. The water quality parameters synchronously monitored in this study, including dissolved oxygen, ammonia nitrogen, pH, temperature, and salinity, can clearly and completely explain the mechanism underlying the aforementioned growth differences. Combined with the inherent euryhaline adaptation trait of *L. vannamei*, we further reached the comprehensive judgment that salinity and farming density jointly affect total farming output. Finally, this study puts forward practical farming configuration recommendations that support sustainable profitability for the local semi-intensive shrimp farming industry, providing rigorous experimental support for the plan optimization of similar aquaculture projects in the same region.

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