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Research Article

Optimizing shrimp growth and yield production: A comparative study of Pacific white shrimp farms along the Persian Gulf coastline

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Abstract

This study aimed to compare the growth and yield of shrimp in different farms of the Heleh (H1, H2, and H3) and Shif (S1, S2, and S3) shrimp farming complexes and investigate the correlation between stocking density, aeration rate, automatic feeder usage, culture period, and harvested yield. Statistical analysis was performed to compare means for average daily growth rate, mean body weight, final yield (ton), survival rate (SR %), feed conversion ratio (FCR), and specific growth rate (SGR) across different farms. The results showed significant differences ($p<0.05$) between different farms for the parameters under investigation in the Heleh shrimp farming complex, while for Shif, no significant differences were found between different farms for average daily growth rate, FCR, and SGR ($p>0.05$). However, significant differences ($p<0.05$) were observed in SR (%), mean body weight, and final yield between different farms in Shif. Further analysis using Pearson correlation showed a high correlation (R>0.9) between the production level and the stocking density, aeration rate, and culture period. While the production level increased with an increasing number of automatic feeders, no significant correlation was found between these two parameters. Additionally, a positive correlation was observed between the SR (%) and the stocking density and the number of aerators. These results provide valuable insights into the factors that influence shrimp growth and yield, which can be useful for the development of more efficient and sustainable shrimp farming practices in both Heleh and Shif shrimp farming complexes.

Introduction

Shrimp aquaculture has emerged as a vital sector within the global seafood industry, playing a crucial role in meeting the increasing demand for high-quality protein sources (Sharifinia *et al*., 2023a, 2023b). As one of the fastest-growing segments of aquaculture, shrimp farming not only contributes significantly to food security but also supports the livelihoods of millions of people worldwide (Khanjani and Sharifinia, 2022; Khanjani *et al*., 2024; Sharifinia, 2025). With its economic potential, shrimp aquaculture offers opportunities for rural development, job creation, and export revenue, particularly in coastal regions where traditional fishing practices are declining. However, the sustainability of this industry is paramount, as it faces challenges such as environmental degradation, disease outbreaks, and fluctuating market conditions (Boyd *et al*., 2020; Dey and Sanyal, 2023; N'Souvi *et al*., 2024; Tien Nguyen *et al*., 2024). By optimizing farming practices and implementing innovative management strategies, shrimp aquaculture can continue to thrive, ensuring a balance between productivity and ecological responsibility. This highlights the importance of research and development in enhancing shrimp growth, yield, and overall sustainability within this dynamic industry.

Shrimp farming has become a significant contributor to the seafood industry's global production, with the Pacific white shrimp (*Litopenaeus vannamei*) being the most widely cultured shrimp species worldwide (Khanjani and Sharifinia, 2020; Khanjani *et al*., 2023; Sharifinia, 2024; Sharifinia *et al*., 2024). Iran is among the countries that have made significant progress in shrimp farming in recent years, with the Persian Gulf coastline being a major area of shrimp production. However, the industry is not without its challenges, such as disease outbreaks, environmental deterioration, and economic feasibility (Dhar *et al*., 2020; Tacon and Metian, 2008; Yeganeh *et al*., 2020). In order to overcome these challenges and maintain the sustainability of the industry, it is crucial to implement effective management practices (Lightner, 2021). By doing so, the industry can ensure the availability of high-quality shrimp while minimizing the impact on the environment and achieving economic viability. Therefore, it is essential to identify and implement best practices in shrimp farm management to ensure the long-term success of the industry (Flegel, 2019; Bush *et al*., 2021; Delphino *et al*., 2022).

The yield production of shrimp farms is influenced by various management factors. These factors include aeration systems, auto feeders, biosecurity measures, liners, and stocking density, which can all significantly affect the growth and survival of shrimp in aquaculture systems. It is crucial to properly manage these factors to ensure the achievement of maximum yields and profitability. Several studies have explored the influence of these management factors on shrimp farming. For instance, Lim *et al.* (2021) revealed that the aeration rate had a notable impact on water quality, growth performance, and production of Pacific white shrimp. Aeration rate is a critical factor in shrimp farming, as it affects dissolved oxygen levels, which are essential for shrimp growth and survival (Li *et al*., 2006; Suwoyo *et al*., 2021). Studies have reported a positive correlation between aeration rate and shrimp growth and yield (McGraw *et al*., 2001; Ruiz-Velazco *et al*., 2010). However, excessive aeration can also lead to stress and mortality in shrimp. Therefore, optimal aeration rates need to be determined to ensure maximum shrimp growth and yield.

Espinoza-Ortega *et al*. (2023) and Arambul-Muñoz *et al*. (2019) observed that feeding strategies and stocking densities influenced the survival and growth of Pacific white shrimp. Additionally, Kring *et al*. (2023) demonstrated that stocking density significantly affected the production, growth, and survival of Pacific white shrimp in greenhouse-based biofloc systems. However, high stocking densities can also lead to poor water quality and disease outbreaks, which negatively impact shrimp growth and yield (Anh *et al*., 2022). Therefore, optimal stocking densities need to be determined to ensure maximum shrimp growth and yield. Besides, the use of auto feeders can help maintain consistent feeding rates and reduce labor costs, resulting in improved growth rates and yields (Inayathullah *et al*., 2021).

Biosecurity measures are also critical in preventing the introduction and spread of pathogens in shrimp farms. Proper biosecurity measures, such as disinfection and quarantine, can significantly reduce the risk of disease outbreaks and prevent economic losses (Delphino *et al*., 2022). Moreover, the use of liners in shrimp ponds can also help prevent the loss of water and improve water quality, resulting in improved growth rates and yields (Fleckenstein *et al*., 2020). Stocking density is another important factor that can significantly impact the yield production of shrimp farms. Overstocking can lead to poor water quality, disease outbreaks, and reduced growth rates, while understocking can result in inefficient use of resources and decreased profitability (Westers *et al*., 2017; Araneda *et al*., 2020). Therefore, it is important to maintain optimal stocking densities to ensure maximum yields and profitability.

The aim of this study is to compare the growth and yield of shrimp in different farms of two shrimp farming complexs (Heleh and Shif). We also aim to investigate the correlation between stocking density, aeration rate, automatic feeder usage, culture period, and harvested yield. The results of this study can provide valuable insights into the factors that influence shrimp growth and yield, which can be useful for the development of more efficient and sustainable shrimp farming practices.

Materials and methods

Ecological conditions of study area:

Bushehr Province is situated between 17°27' to 30°10' North latitude and 50°02' to 52°41' East longitude. Recent studies conducted on the Integrated Coastal Zone Management (ICZM) project indicate that the length of the land coasts in Bushehr Province is 870 kilometers, while its islands stretch for 67 kilometers. The entire sea border of Bushehr Province measures 937 kilometers. The average surface water temperature in the Persian Gulf's Bushehr Province area is 26.6˚C. In detail, this indicator averages 28.2˚C in the spring, 33.4˚C in the summer, 24.9˚C in the autumn, and 19.8˚C in the winter. Moreover, the average salinity of the Persian Gulf in the Bushehr Province area is 42 ppt, with averages of 39.7 ppt in the spring, 39.6 ppt in the summer, 40.2 ppt in the autumn, and 40.4 ppt in the winter (Izadpanahi *et al*., 2005). Despite the aforementioned ecological conditions, the cultivation of Pacific white shrimp in the shrimp farms of Bushehr Province occurs in salinity levels exceeding 47 ppt, pH range of 7.8 to 3.7, and temperature ranges of 25 to 38 degrees Celsius. Notably, there are currently nine shrimp farming complexes in the province, consisting of 20-hectare farms, each containing 14 to 20 ponds. The shrimp cultivation period in Bushehr Province takes place once a year, from late April to late November.

Study area

The current study was carried out in two major shrimp farming complexes located in Bushehr Province, namely Shif and Heleh (Fig. 1). For the purpose of this research, three farms were selected from each of the aforementioned complexes, and the various stages of shrimp farming management were meticulously monitored throughout a one cultivation cycle. To this end, both field visits and information obtained from farm managers through questionnaires were employed, in collaboration with the Iran Shrimp Research Center. The field visits were conducted every 14 days across the three shrimp farming complexes in Bushehr Province to ensure a comprehensive and exhaustive analysis of the shrimp farming management practices.

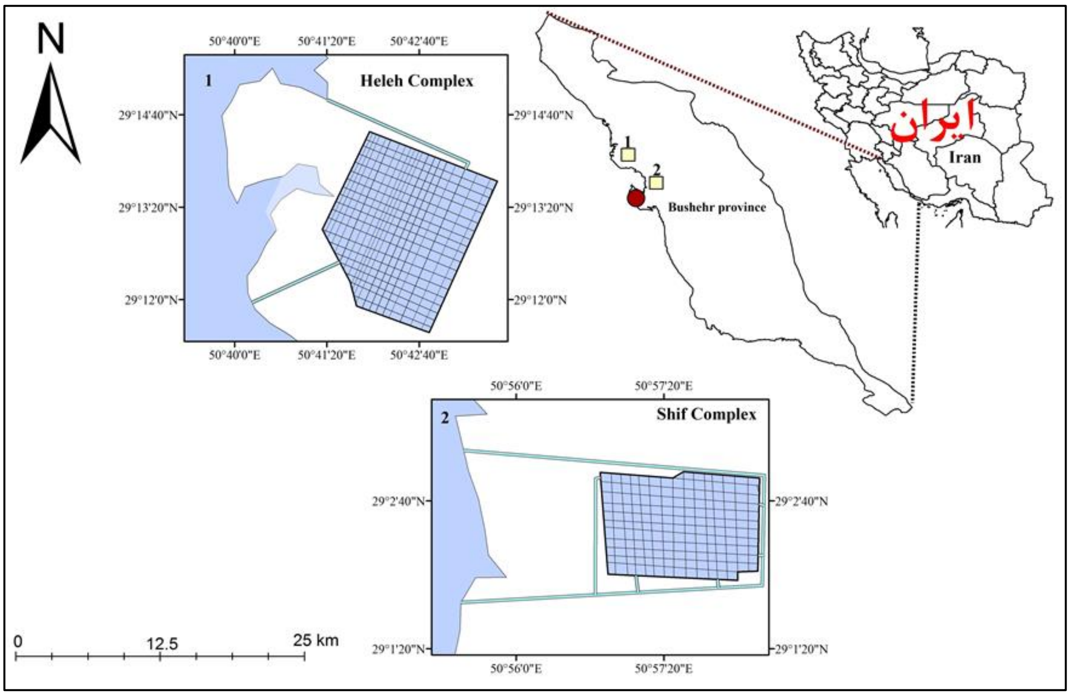

Figure 1: Geographical location of studied shrimp farming complexes (Delvar, Shif, and Heleh).

The Shif shrimp farming complex is located at 29˚04' N and 50˚57' E, about 30 kilometers northeast of Bushehr city. It covers an area of 2,169.6 hectares and includes 103 farms. The Heleh shrimp farming complex is located at 29˚13' N and 50˚44' E, approximately 110 kilometers northwest of Bushehr city. It is situated between two estuaries, Ghasir and Ramleh, at the end of the Heleh river in the Rig district of Genaveh city. It covers an area of 3,858 hectares and includes 67 farms. The water source for these complexes is gravity-fed from the sea through a canal, and it is pumped into the farms for use. In this study, three farms were selected from each shrimp farming complex, and three ponds were chosen from each farm for sampling and statistical purposes. In total, 18 ponds were sampled.

Growth performance

At the end of the shrimp farming cycle, body weight gain (BWG; g), feed conversion ratio (FCR), specific growth rate (SGR; %), Daily growth rate (g/day), and survival rate (SR; %) carried out using the following formulas:

$$\text{BWG (g)} = \text{Final weight} - \text{Initial weight}$$

$$\text{FCR} = {\text{Feed given (g)}}/{\text{Alive weigh gain (g)}}$$

$$\text{SGR} = \left({\text{Ln(W2)} - \text{Ln(W1)}}/{\text{Culture days}}\right) \times 100$$

$$\text{Daily growth rate } \left(\frac{\text{g}}{\text{day}}\right) = \left({\text{Average final weight} - \text{Average initial weight}}\right)/{\text{Days between sampling}}$$

$$\text{SR (\%)} = \left[{\text{Final number of shrimp}}/{\text{Initial number of shrimp}}\right]$$

Statistical analyses

The results of growth and production parameters were expressed as mean±standard deviation. One-way ANOVA was used to analyze the data, and then Duncan's test was performed to determine the significance of differences between treatments at the 0.05 level of probability. Pearson correlation was used to investigate the correlation between different parameters and production. Statistical analysis was performed using SPSS 22 software, and Excel software was used to draw graphs.

Results

The harvest yield from the studied shrimp farming complexes

The results of the yield harvest from the studied complexes in this study are shown in Figure 2. Out of a total of 18,800 tons harvested, the minimum and maximum yields were obtained from Heleh and Shif farms, with 6,200 tons (33%) and 12,600 tons (67%), respectively. Also, the minimum and maximum production per unit area were obtained from Heleh (7.22 tons per hectare) and Shif (7.43 tons per hectare) farms, respectively (Fig. 3).

Growth performance

The results of the present study on the average weight gain, mean daily growth rate, mean body weight, final yield harvest, survival rate percentage, FCR, SGR, Daily growth rate, and production per unit area (hectare) in the ponds of the shrimp farms studied in the Heleh and Shif complexes are presented in Figures 3 and 4.

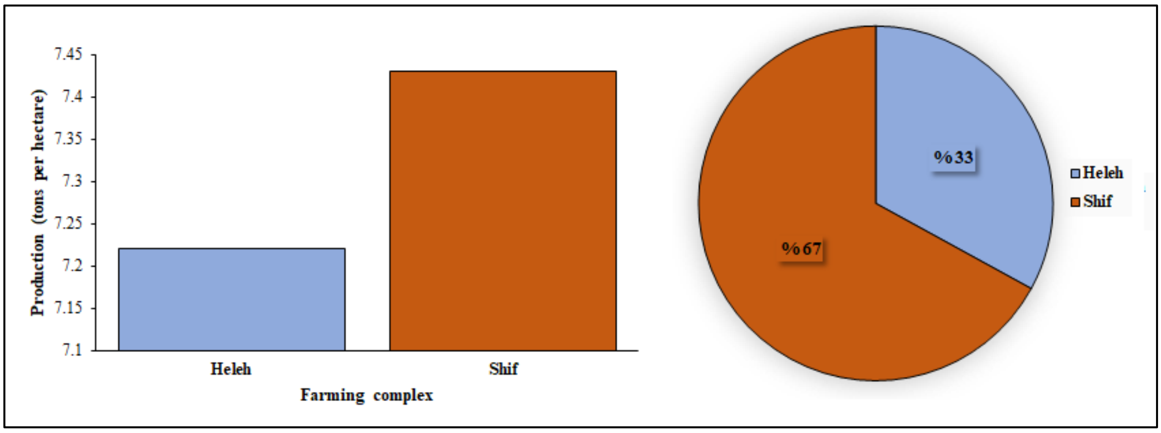

Figure 2: The percentage of harvest yield and production per unit area (tons per hectare) in Shif and Heleh complexes.

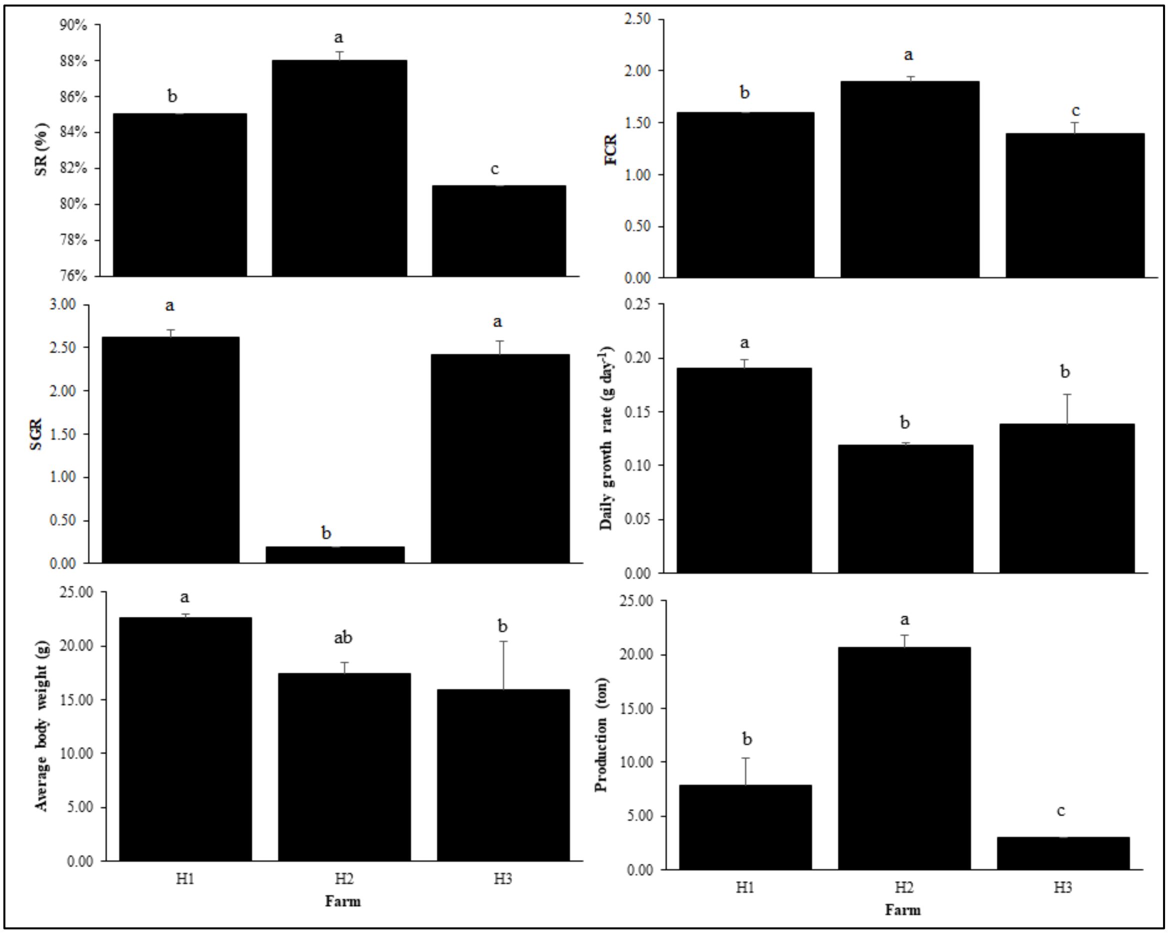

Figure 3: Growth and nutrition indices (mean ± standard deviation) of Pacific white shrimp (*Litopenaeus vannamei*) in the farms studied in the Heleh shrimp farming complex during one farming period in 2022.

Heleh complex

The results of the statistical analysis comparing means using the ANOVA test for average daily growth rate, mean body weight, final yield, SR, FCR, and SGR in different farms studied in the Heleh shrimp farming complex are presented in Figure 3. The results indicate significant differences (p<0.05) between different farms for the parameters under investigation.

Shif complex

The results of the statistical analysis comparing means for average daily growth rate, mean body weight, final yield (ton), SR (%), FCR, and SGR in different farms studied in the Shif shrimp farming complex are presented in Figure 4. The results did not show significant differences between different farms for average daily growth rate, FCR, and SGR ($p>0.05$). The SR (%) in different farms showed significant differences ($p<0.05$), with the minimum and maximum values obtained from farms S3 and S1, respectively. Moreover, the mean body weight and final yield showed significant differences ($p<0.05$) between farm S3 with farms S1 and S2.

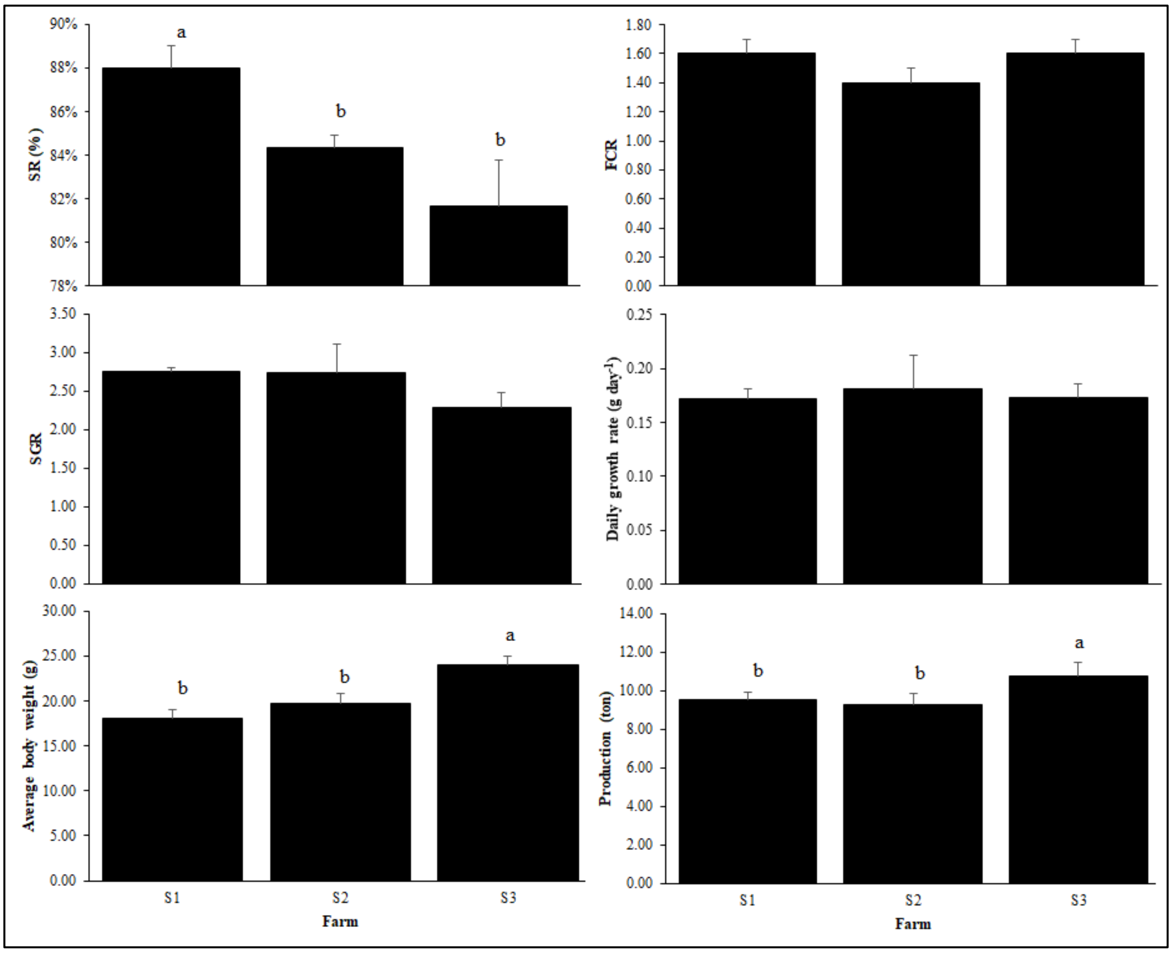

Figure 4: Growth and nutrition indices (mean ± standard deviation) of Pacific white shrimp (*Litopenaeus vannamei*) in the farms studied in the Shif shrimp farming complex during one farming period in 2022.

The relationship between different parameters

The results of Pearson correlation analysis between the stocking density, number of aerators, number of automatic feeders, and the culture period with the harvested yield are presented in Figure 5. According to the results, a high correlation (R>0.9) was observed between the production level and the stocking density, aeration rate, and culture period. Although the production level increased with increasing the number of automatic feeders, no significant correlation was found between these two parameters. In addition, a positive correlation was observed between the SR (%) and the stocking density and the number of aerators (Fig. 5).

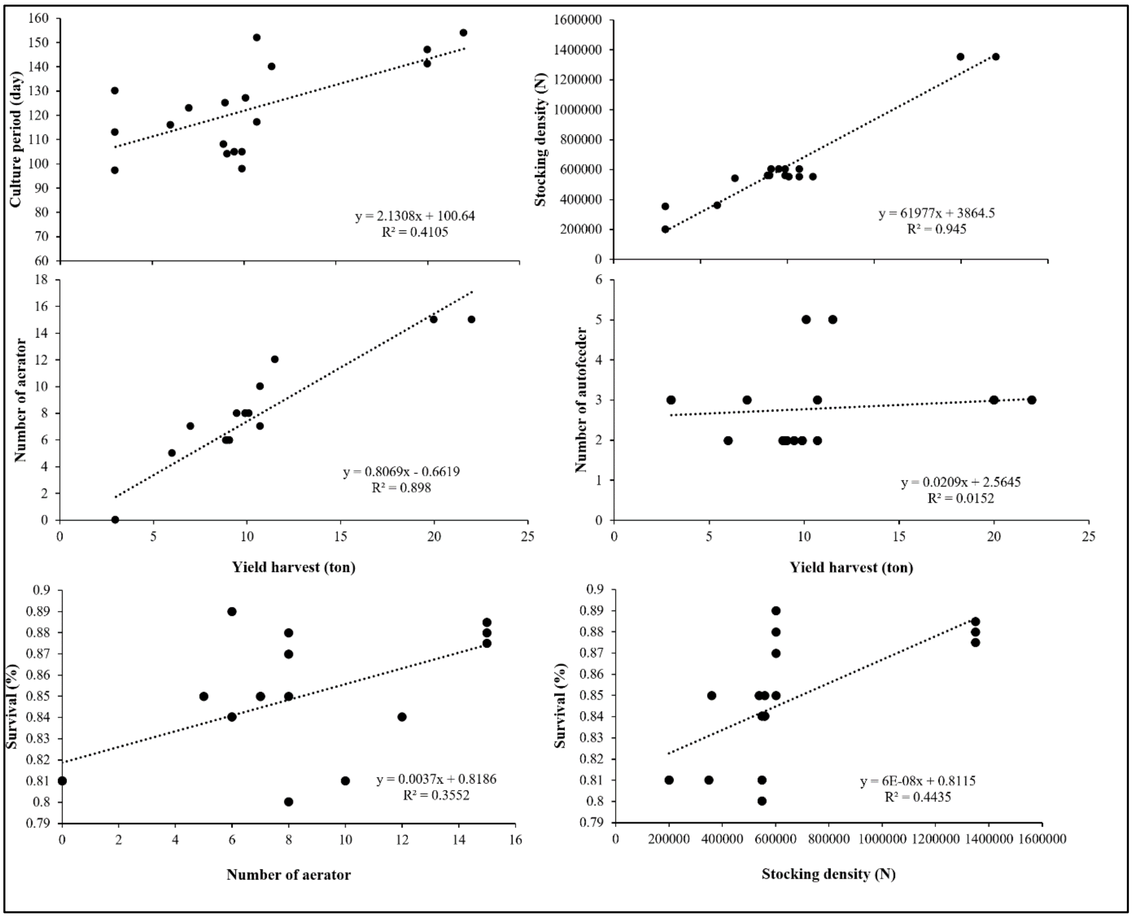

Figure 5: Pearson correlation analysis between the stocking post-larvae, number of aerators, number of automatic feeders, and the culture period with the production level and survival rate (%) with stocking density and number of aerators in the farms of Heleh and Shif complexes.

Discussion

The shrimp farming industry is at a pivotal juncture, where optimizing growth and yield production is not just a goal but a necessity for sustainability and economic viability. This comparative study of Pacific white shrimp farms along the Persian Gulf coastline sheds light on the intricate dynamics that govern shrimp cultivation. By meticulously analyzing various parameters such as stocking density, aeration rates, automatic feeder usage, and culture periods, we have unveiled critical insights that can significantly enhance production efficiency. The results of this study provide valuable insights into the factors that influence shrimp growth and yield in different shrimp farming complexes. The statistical analysis showed significant differences in the average daily growth rate, mean body weight, final yield, SR (%), FCR, and SG) between different farms in the Heleh shrimp farming complex. On the other hand, no significant differences were observed in average daily growth rate, FCR, and SGR between different farms in the Shif shrimp farming complex. However, significant differences were observed in SR (%), mean body weight, and final yield between different farms in the Shif complex.

The results of Pearson correlation analysis showed a high correlation between the production level and stocking density, aeration rate, and culture period. These findings suggest that the optimal stocking density, aeration rate, and culture period are critical factors for maximizing shrimp growth and yield. Furthermore, a positive correlation was observed between the SR (%), the stocking density, and the number of aerators. This indicates that higher stocking densities and aeration rates may result in better survival rates of shrimps. The lack of significant differences in some growth and yield parameters between different farms in the Shif complex may be due to similar environmental conditions, management practices, and/or genetic characteristics of the shrimps. In contrast, the significant differences observed in the Heleh complex could be attributed to differences in the aforementioned factors.

Several previous studies have reported similar findings on the effects of stocking density, aeration rate, and culture period on shrimp growth and yield (Sookying *et al*., 2011; Fleckenstein *et al.*, 2020*;* Lim *et al*., 2021). For example, a study conducted by Lim *et al*. (2021) found that increasing stocking density and aeration rate significantly improved shrimp growth and yield. Similarly, Robertson *et al*. (1993), Peixoto *et al*. (2018), and Carvalho and Nunes (2006) reported that optimizing culture period and feeding practices can enhance shrimp growth and yield.

The positive correlation between stocking density and shrimp yield observed in this study is consistent with the findings of other studies. For example, a study by Wasielesky *et al*. (2013) found that increasing stocking density resulted in higher shrimp biomass production. Similarly, a study by Kring *et al*. (2023) reported that high stocking densities can lead to increased shrimp yields, although this can also have negative impacts on water quality and environmental sustainability. The positive correlation between the aeration rate and shrimp survival rate observed in this study is also consistent with previous studies (McGraw *et al*., 2001; Harun *et al*., 2019). These studies reported that increasing aeration rates can improve water quality, shrimp growth, and survival rates.

Overall, the findings of this study provide further evidence to support the importance of optimizing stocking density, aeration rate, and culture period for maximizing shrimp growth and yield. However, it is important to consider the potential negative impacts of high stocking densities on water quality and environmental sustainability. Moreover, implementing sustainable shrimp farming practices, such as proper feeding practices and minimizing environmental impacts, can enhance the long-term economic and environmental viability of shrimp farming. Future research should focus on developing more efficient and sustainable shrimp farming practices that take into account these potential trade-offs.

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Confilicts of interest

The authors declare that they have no cconflicts of interest.

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