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Original Article

# Green mussel (*Perna viridis*) culture in recirculating aquaculture system: A performance evaluation from Cox's Bazar, Bangladesh

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**Abstract:** This research assesses the growth performance of green mussels, *Perna viridis*, cultivated in a Recirculating Aquaculture System (RAS) in Cox's Bazar, Bangladesh. Mussels were cultivated under three distinct treatments (T1, T2, and T3), with variations in key environmental parameters recorded from stocking to harvesting. T2 demonstrated the greatest ultimate weight (55.55±0.21 g), length (10.45±0.10 cm), and width (3.51±0.06 cm), followed by T1, while T3 revealed the least growth performance (50.5±0.09 g, 9.07±0.06 cm, and 3.59±0.06 cm, respectively). The water quality parameters remained within an acceptable range, with temperatures ranging from 26.9±0.59 to 32.2±0.83°C, pH levels varying between 7.10±1.16 and 7.92±2.75, and dissolved oxygen levels ranging from 4.62±0.28 to 5.31±0.31 ppm. Ammonia and nitrite concentrations were also lowest in T2 (0.01±0.01 mg/L and 0.05±0.02 mg/L, respectively), suggesting better water quality management. The findings indicate that RAS provides a controlled environment conducive to mussel growth, with T2 conditions being the most optimal. This research highlights the practicality of incorporating RAS into green mussel cultivation as a viable alternative to traditional methods in Bangladesh.

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## Introduction

Aquaculture is essential for ensuring global food security and providing a sustainable protein source to meet the needs of an expanding population. Bangladesh possesses distinctive aquatic resources that are conducive to the advancement of aquaculture. Bangladesh is known for its diverse marine aquatic biodiversity, with around 1093 marine aquatic organisms, including 44.35% finfish, 32.23% shellfish, 15.10% seaweeds, and 8.32% other organisms such as shrimps (Ghose, 2014). Around 317 mollusk species have been identified in Bangladesh, with 125 species classified among 19 families of bivalves (Hossain et al., 2014).

The green mussel, *Perna viridis*, is an indigenous bivalve species found in the Indo-Pacific Region (Noor et al., 2019). It is also prevalent in tropical and subtropical coastal waters and is valued for its rapid growth, nutritional value, and ecological benefits. It is a large, fast-growing marine bivalve that is an intertidal filter feeder (Rajagopal et al., 2006) that attains maturity rapidly and has remarkable resilience to various contaminants, salt levels, and water temperatures (McDonald, 2012). *Perna viridis* has commercial significance because of its accelerated growth rate and high population densities (Rajagopal et al., 1998). The cultivation of *P. viridis* is linked to various ecological advantages, as these filter-feeding bivalves significantly improve water quality by removing organic particulates (Melendres and Largo, 2021).

The demand for green mussels has increased significantly in recent years, attributed to their culinary versatility and heightened awareness of their environmental advantages. Factors that facilitate the advancement of green mussel aquaculture include the comparatively rapid growth rate of green mussels, which necessitates a brief culture duration to attain a

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marketable size (Loekman et al., 2018; Liyana et al., 2019). The traditional cultivation of green mussels predominantly depends on open-water systems, which frequently encounter environmental fluctuations, pollution, and biofouling. Recirculating aquaculture systems (RAS) have emerged as a compelling alternative to address these challenges. RAS establishes a regulated setting that enhances water quality, ensures biosecurity to mitigate external contamination risks, and diminishes the ecological impact of aquaculture practices while also lowering direct operational expenses related to feed, predator management, and parasites (Aich et al., 2020).

Cox's Bazar, situated on the southeastern coast of Bangladesh, presents advantageous circumstances for the advancement of aquaculture, owing to its rich coastal resources and appropriate climatic conditions. Nevertheless, the existing body of research concerning the cultivation of green mussels in this region remains sparse, particularly in controlled aquaculture systems like RAS. This research evaluates green mussels' growth performance within a recirculating aquaculture system located in Cox's Bazar, Bangladesh. Key parameters, including shell length, weight gain, and survival rate, will be evaluated to ascertain the viability and prospective advantages of incorporating RAS into mussel aquaculture. The findings seek to facilitate the sustainable growth of green mussel farming in Bangladesh, fostering economic advancement while promoting environmental conservation.

## Materials and Methods

**Study area:** Before designing the experimental apparatus, an initial survey was conducted in the selected locale (21°32'27.8"N, 91°59'34.7"E). The experiments, which employed open culture and RAS culture methodologies, were conducted at the Bangladesh Fisheries Research Institute (BFRI) in Cox's Bazar, Bangladesh, over a 12-month period, specifically from February 2023 to February 2024.

**Experimental setup:** The experimental RAS consisted of two treatment groups (T1 and T2) and one control group (T3). Each treatment consisted of two replications. The design comprised rectangular tanks with a capacity of 1000L for cultivating green mussel, 600L clarifiers for solid removal, biofilters for nitrification, degassing chambers to eliminate dissolved gases from the water, 700L plant filters, and 500L reservoir tanks. Each treatment consisted of two rectangular tanks with a capacity of 1000 L, designated for cultivating green mussels, and two clarifiers of 600 L for solid removal. Additionally, there were two biofilters for the nitrification process, two degassing chambers designed to eliminate dissolved gases from the water, two plant filters with a volume of 700 liters, and two reservoir tanks of 500 liters each. For the control, a 1000-liter stocking tank and a 700-liter plant filter were considered. RAS was absent in the control group.

**Green mussel collection and stocking:** A total of 125 green mussels, each weighing approximately 40±2 grams, were collected from the Moheshkhali channel. Within 24 hours, green mussels were allocated to the culture tanks, including treatment groups 1 and 2 and the control. This study utilized three distinct stocking techniques to assess the growth performance of the mussels. In the first treatment (T1), 60 green mussels were distributed across two circular stocking tanks, each with a capacity of 1000 liters, resulting in 30 mussels per tank. In the second treatment (T2), 40 green mussels were distributed across three circular stocking tanks, with 20 mussels in each tank. In the control group (T3), 25 green mussels were in the stocking tank. Twenty-four hours. Continuous aeration was implemented in each culture tank.

**Feeding of the muscle:** Three species of marine microalgae were used as feed for green mussels, namely *Nannochloropsis* spp., *Nannochlorum* spp., and *Tetraselmis* spp. Each strain was cultivated from internal culture stocks within eight 800 L conical bottom tanks. Each culture tank was supplied with 3 liters of live feed daily, administered in two separate instances of 1.5 liters each. The aeration and recirculation of water were halted during the feeding process of the Green Mussel. Following a 30-minute duration, the feeding, aeration, and water recirculation processes were reinstated.

**Water quality monitoring:** Water quality was monitored every 15 days. The physicochemical parameters of the water, including dissolved oxygen (DO), pH, salinity, temperature, ammonia, and nitrite, were measured using a HI 9829 Multi-Parameter Water Quality Checker (Hanna Instruments).

**Growth monitoring:** The dimensions—length, width, depth, and weight of the green mussel were meticulously recorded on-site at the cultivation site (Putra et al., 2022). The length of the shell was measured using a digital slide caliper, which boasts an accuracy of 1 mm. To quantify the total weight of the green mussel, a digital scale calibrated in grams with an accuracy of 0.1 grams was employed.

**Absolute weight gain:** The absolute weight increase is the difference between the final and initial weights during maintenance. The absolute weight gain was estimated using the formula of Wm = Wt–Wo, where Wm = Absolute weight gain (gr), Wt = Average weight at the end of the study (gr), and Wo = Average weight at the beginning of the study (gr).

**Absolute length gain:** Absolute length growth was calculated using the formula of Lm = Lt – Lo, where Lm = Absolute length gain (mm), Lt = Average length at the end of the study (mm), and Lo = Average length at the beginning of the study (mm).

**Daily weight growth rate (DWG) / DGR (W):** The daily weight rate was calculated using the formula of DGR (W) = Wm/t, where DGR (W) = Daily weight growth rate (gr/day), Wm = Total weight gain (gr), and t = Maintenance time (day).

Daily length growth rate (DGR) (L): The daily length growth rate was calculated using the formula of DGR (L) = Lm / t, where DGR (L) = Daily weight growth rate (mm/day), Lm = Absolute length gain (mm), and t = Maintenance time (day).

**Specific weight growth rate:** SGR Specific Weight Growth Rate (SGR %/day) of the weight (SGR G) of green mussels was calculated using the formula of SGR (W) = ((LnWt-LnWo) / t) × 100%, where, Wo = Initial weight (g), Wt = Final weight (g), and t = period of cultivation of green mussel.

**Specific length growth rate:** The specific Length Growth Rate (SGR %/day) of the length (SGR L) of green mussels was calculated using the formula of SGR (L) = ((LnLt-LnLo) / t) × 100%, where Lo = Initial length (mm), Lt = Final length (mm), and t = time of cultivation of green mussel.

**Survival rate (SR):** The percentage of Survival Rate (SR) was calculated based on the following formula: SR = ((No - Nt) / No) x 100%, where SR = Survival Rate (%), Nt = Total number of survival oysters at the end of the study, and No = Total number of oysters at the beginning of the study.

**Statistical analysis:** MS Excel 2021 and SPSS were used to analyze the experiment's data and present the results in tabular and graphical forms to illustrate the current data. The growth performance of green mussels was determined by statistically analyzing the data for each treatment using a one-way ANOVA analysis of variance.

## Results

**Growth performance:** Initially, 40.62±0.17 g of green mussels were stocked in different rectangular plastic tanks. After the final sampling of the experiment, higher final weights were found in T2 (55.55±0.21 g), followed by T1 (54.03±0.45 g) and T3 (50.5±0.09 g), respectively (Table 1). A significantly higher yield was observed in treatment two (T2) among the three treatments. Initially, green mussels with 7.47±0.11 cm length were stocked in different rectangular plastic tanks. After the last sampling of the experiment, the highest final length was found in T2 (10.45±0.11 cm), followed by T1 (9.73±0.01 cm) and T3 (9.07±0.06 cm), respectively (Table 1). Initially, green mussels with 3.37±0.03 cm width were stocked in different rectangular plastic tanks. After the final sampling of the experiment, higher final widths were found in T2 (3.91±0.04 cm), followed by T1 (3.86±0.02 cm) and T3 (3.59±0.06 cm), respectively (Table 1). A significantly higher yield was observed in T2. In the case of specific weight growth rate and specific length growth rate, the highest and lowest mean value was found in T2 (0.35±0.01 and 0.36±0 %day$^{-1}$; 0.16±0.01 g.day$^{-1}$) and T3 (0.25±0.003 and 0.23±0.002 %day$^{-1}$;

Table 1. Growth performance of the Green Mussel, *Perna viridis*, in different treatments.

| Treatment | Weight | | | |
|---|---|---|---|---|
| | Stocking data | 1st Sampling data | 2nd Sampling data | Harvesting data |
| T1 | 40.63±0.07ᵃ | 44.62±0.21ᵃ | 49.31±0.3ᵇ | 54.03±0.4ᵇ |
| T2 | 40.72±0.24ᵃ | 45.43±0.12ᵃ | 50.6±0.17ᵃ | 55.55±0.21ᵃ |
| T3 | 40.52±0.04ᵃ | 43.45±0.01ᵃ | 46.9±0.20ᶜ | 50.5±0.09 ᶜ |
| | Length | | | |
| T1 | 7.47±0.11ᵃ | 8.18±0.04ᵇ | 8.98±0.04ᵃ | 9.73±0.01ᵃ |
| T2 | 7.53±0.25 ᵃ | 8.47±0.36ᵃ | 9.45±0.04ᵃ | 10.45±0.10ᵃ |
| T3 | 7.37±0.07 ᵃ | 7.99±0.08 ᶜ | 8.51±0.03ᵃ | 9.07±0.06ᵃ |
| | Width | | | |
| T1 | 3.34±0.01ᵃ | 3.52±0.01ᵃ | 3.67±0.04 ᵇ | 3.86±0.02 ᵃ |
| T2 | 3.42±0.03 ᵃ | 3.52±0.07 ᵃ | 3.74±0.08 ᵃ | 3.51±0.06ᶜ |
| T3 | 3.36±0.06 ᵃ | 3.42+0.03 ᵃ | 3.51±0.06ᶜ | 3.59±0.06 ᵃ |

*Data are represented as Mean±Standard deviation (SD) at a significant level *P*<0.05.

Table 2. Mean values of the green mussel, *Perna viridis*, growth performance recorded from different treatments.

| Parameters | (T1) | (T2) | (T3) Control |
|---|---|---|---|
| Initial weight (g) | 40.63±0.07 | 40.72±0.24 | 40.52±0.04 |
| Final weight (g) | 54.03±0.45 | 55.55±0.21 | 50.5±0.09 |
| Weight Gain (g) | 13.4±0.38 | 14.83±0.45 | 9.97±0.13 |
| SWGR (%day$^{-1}$) | 0.32±0.01 | 0.35±0.01 | 0.25±0.003 |
| DWG (g/day) | 0.15±0.04 | 0.16±0.01 | 0.11±0.001 |
| Initial length (cm) | 7.47±0.11 | 7.53±0.25 | 7.37±0.07 |
| Final length(cm) | 9.73±0.01 | 10.45±0.11 | 9.07±0.06 |
| Length gain (mm) | 22.5±0.10 | 29.17±0.10 | 17±0.00 |
| SLGR (%day$^{-1}$) | 0.29±0.01 | 0.36±0.0 | 0.23±0.002 |
| DLG (mm.day$^{-1}$) | 0.25±0.01 | 0.32±0.01 | 0.19±0.00 |
| Survival rate (%) | 83.33 | 87.50 | 58.00 |

0.11±0.001 g.day$^{-1}$) treatments and also the highest mean value of the daily weight and length gain was recorded in treatment two (0.16±0.01 g day$^{-1}$ and 0.32±0.01 mm day$^{-1}$), respectively (Table 2). The survival rates were 83.33, 87.50, and 58.00% for T1, T2, and T3 treatments, respectively.

**Measurement of water quality parameters**: Various water quality parameters, including temperature (℃), dissolved oxygen (ppm), pH, ammonia (mg/L), salinity, and nitrate (mg/L), for the studied treatments are presented in Table 3. The temperature varied between 26.9±0.59 (T2) and 32.2±0.83°C (Control), with T1 at 29.0±0.7°C. The pH values varied slightly, with the lowest in T2 (7.10±1.16) and the highest in the control (7.92±2.75). Dissolved oxygen levels were greatest in T2 (5.31±0.31 ppm) and lowest in the control (4.62±0.28 ppm). T2 had the lowest ammonia and nitrite levels (0.01±0.01 and 0.05±0.02 mg/L, respectively), whereas the control one had the highest values (0.08±0.02 and 0.22±0.05 mg/L). Salinity levels were generally steady, ranging from 28.6±0.59 (T2) to 32.2±0.83 ppt (Control group). These findings suggest that T2 provided the most optimal water quality conditions, particularly in maintaining lower ammonia and nitrite concentrations while ensuring higher dissolved oxygen levels, which are critical for the sustainable culture of *P. viridis* in RAS.

## Discussions

Green mussel farming is a significant industry in many coastal countries, including Bangladesh. Their high protein content, rich omega-3 fatty acids, and essential minerals make them a nutritious seafood choice. However, there is a lack of research on green muscle culture in RASs. The study assesses the effectiveness of *P. viridis* cultivation in an RAS in Cox's Bazar,

Table 3. Different water quality parameters in various treatments during the study period.

| Parameters | (T1) | (T2) | (T3) Control |
|---|---|---|---|
| Temperature (˚C) | 29.0±0.7 | 26.9±0.59 | 32.2±0.83 |
| pH | 7.32±1.14 | 7.10±1.16 | 7.92±2.75 |
| Dissolved Oxygen (ppm) | 5.06±0.37 | 5.31±0.31 | 4.62±0.28 |
| Ammonia (mg/L) | 0.025±0.02 | 0.01±0.01 | 0.08±0.02 |
| Nitrite (mg/L) | 0.07±0.02 | 0.05±0.02 | 0.22±0.05 |
| Salinity (ppt) | 29.13±0.71 | 28.6±0.59 | 32.2±0.83 |

Bangladesh. The results demonstrate the potential of RAS as an alternative to conventional open-water mussel farming, especially in terms of environmental and sustainability considerations.

Daily weight gain at T1 averaged 0.15 ±0.04 g.day$^{-1}$, T2 averaged 0.16±0.01 g.day$^{-1}$ and T3 averaged 0.11±0.001 g.day$^{-1}$. The average daily length growth rate at T1 was 0.25±0.01 mm.day$^{-1}$, at T2 0.32±0.01 mm.day$^{-1}$, and in T3 0.19±0.00 mm.day$^{-1}$. The growth rates of a specific weight at T1, T2, and T3 were 0.32±0.01, 0.35±0.01, and 0.25±0.003 %day$^{-1}$. The growth rates of a specific length at T1, T2, and T3 were 0.29±0.01, 0.36±0, and 0.23±0.002 %day$^{-1}$. According to the study of Putra et al. (2022), the daily growth rate (weight) of green mussel was 0.11±0.004 g day$^{-1}$, which is similar to the T3, but in T1 and T2, the daily weight growth rates were higher in the experiment of the indoor culture of green mussel in RAS. The specific weight growth rate was higher than that reported by Putra et al. (2022) in all three treatments. The green mussel cultivation treatment over 3 months (90 days) demonstrated optimal weight and length gain in treatment 2, which recorded an absolute weight gain of 14.83 g and an absolute length increase of 29.17±0.10 mm. The daily weight growth rate was 0.16±0.01 g/day, while the daily length growth rate was 0.32 ± 0.01 mm/day. The specific weight growth rate was 0.35±0.01 %/day, the specific length growth rate was 0.36±0 %/day, and the survival rate was 87.5%. This contrasts with the findings of Sagita et al. (2017), where green mussel cultivation over 60 days at varying stocking densities and a depth of 1.5 meters demonstrated optimal weight and length gains with a density of 20 individuals, yielding a specific weight growth rate of 1.18±0.04 % per day and a specific length growth rate of 0.86±0.01 % per day. The conclusive weight observed at the 90-day mark of this study revealed an average weight of 12.73±0.32 g/head, accompanied by an average length of 22.89±0.05 mm, closely aligning with the findings of Putra et al. (2022). This is based on the results of Yonvitner and Sukimin (2009), which state that the maximum length of green mussels can reach more than 10 cm and grow between 0.5 and 0.9 cm in a month. According to Taib et al. (2016), the maximum length observed in 12 months of monitoring was 110 mm, and the predicted extreme length of the mussel was 129.03 mm. The absolute length gain in 12 months was reported in other places in Malaysia, including Malacca (102.38 mm) and Penang (89.4 mm) (Al-Barwani et al., 2007). This value resembles those reported in other Asian countries, particularly in Hong Kong and Thailand, at 101.9 mm and 112 mm, respectively (Lee, 1985; Tuaycharden et al., 1988). The absolute length gain in the current study of 90 days of green mussel culture in RAS is nearly similar to those of these studies.

Water parameters are important for green mussel culture in closed aquaculture systems. The water temperature for green mussel cultivation throughout the research varied between 26.9 and 32.2°C. According to Sagita et al. (2017) and Noor et al. (2021), the water temperature for green mussel cultivation throughout the research varied between 27.5 and 34.0°C. According to Soon and Ransangan (2014), green mussels may survive in a wide salinity range of 5.2-39.8 ppt; however, optimal development requires a salinity of 27-35 ppt (Soon and Ransangan 2016; Asaduzzaman et al., 2020). The pH levels observed in the research remained within the usual range of 7.10 to 7.92 for *P. viridis*, with the optimal pH for green mussels spanning from 6 to 8.2

(Asaduzzaman et al., 2020). Susetya et al. (2021) recorded a pH range of 7.33 to 7.88 for *P. viridis* culture. The pH value is inversely correlated with nitrate and phosphate, which serve as indications of the availability of a food supply for green mussels, namely phytoplankton. Phytoplankton use nitrate and phosphate as essential nutrients for photosynthesis. In the current study, we found 0.05 to 0.22 mg/L nitrate, whereas Susetya et al. (2021) recorded 2.63 to 3.24 mg/L nitrate in *P. viridis* culture. DO level may not directly influence the cultural potential of green mussels; instead, their energy-intensive selective feeding behaviors need a high oxygen concentration (Bayne, 1998). In the current work, DO remained at 4.62 to 5.31 ppm, whereas Susetya et al. (2021) got 6.64 to 8.43 ppm in green mussel culture.

Green mussels in the closed environment have good survival and growth rates, which suggests that they might be cultured in recirculating systems with artificially generated seawater and live feeding. Green mussels raised in recirculating aquaculture systems have both intrinsic benefits and drawbacks for their health. In general, these systems make it easier to monitor and manage environmental and water quality issues; however, organic materials and possibly hazardous waste products can hinder the development of these organisms or be harmful to green mussels, which are intended to be eaten raw. High stocking densities are possible with most recirculation systems, although some infectious pathogens can spread quickly because of the tight quarters of the animals. These are important considerations for inland green mussel production, and the benefits can outweigh the drawbacks. Furthermore, there are benefits to controlled research and trials when green mussels are cultivated in a managed land-based system.

## Conclusions

The study on the culture of *P. viridis* in an RAS in Cox's Bazar, Bangladesh, highlights the feasibility and potential of this approach for sustainable bivalve aquaculture. The results indicate that RAS provides a controlled environment with stable water quality parameters, ensuring optimal growth and survival of *P. viridis*. Compared to traditional open-water mussel farming, RAS offers advantages such as reduced exposure to environmental pollutants, lower disease risks, and enhanced biosecurity. However, further research on cost-effectiveness, feed optimization, and long-term viability is necessary to establish RAS as a scalable alternative for green mussel aquaculture in Bangladesh. Adopting RAS for *P. viridis* culture can contribute to sustainable seafood production, reduce pressure on natural marine resources, and support the economic upliftment of coastal communities.

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