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EFFECTS OF FEEDS ON SELECTED SHELLFISH (*MACROBRACHIUM ROSENBERGII*) AND FINFISHES (*PLANILIZA PERSIA* AND *RHINOMUGIL CORSULA*) IN POLYCULTURE SYSTEM: PROFITABILITY AND VIABILITY

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Abstract

The experiment was conducted at earthen ponds in the Bagerhat sadar upazila of Bagerhat to examine the growth, production capacity, and economic return of freshwater prawn (*Macrobrachium rosenbergii*) with persa (*Planiliza persia*) and corsula mullet (*Rhinomugil corsula*) under polyculture system. Four treatments, designated as T_1, T_2, T_3, and T_4 were used in the study, each with three replicates. The final weight of the prawns after 120 days of culture was highest in T_1 (72.07 g) and lowest in T_4 (50.23 g), but there was no significant difference in prawn growth between T_1 and T_2. In T_4, where artificial feed was not employed, prawn, persa, and corsula mullet growth and survival rates were lower. T_1 produced more prawns (173.27 kg ha^{-1}), while T_4 produced less (617.83 kg ha^{-1}). Significantly ($p<0.05$) higher production of persa was found in T_1 (295.97 kg ha^{-1}) and lower in T_4 (152.28 kg ha^{-1}). Corsula production was also observed to be higher in T_1 (275.70 kg ha^{-1}) and lower in T_4 (155.36 kg ha^{-1}). However, T_1 had much higher total production and net profit from prawn and fish farming (1744.94 kg ha^{-1}, BDT 244694.75 ha^{-1}), whereas T_4 had a significantly lower total production and net profit (925.46 kg ha^{-1}, BDT 115894.42 ha^{-1}). According to the study, quality feed (T_1) outperforms other commercial feeds in terms of growth, production, and net profit. In order to increase productivity and get a high return on investment in a short period of time. The quality feed can be recommended.

Key words: Polyculture, Survival rate, Economic return, Water quality.

Introduction

The nation's socioeconomic development is significantly influenced by the resources of the fishing industry. The fisheries sector provides 3.52% of the national GDP and 26.37% of the entire agricultural GDP. More than 12% of Bangladesh's almost 170 million people rely on fisheries and aquaculture-related activities for their livelihoods, either full- or part-time. Bangladesh produced enough fish to meet its own needs, consuming 63.01 g of fish per capita per day as opposed to the goal of 60 g (DoF, 2020).

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Both "golda" (*Macrobrachium rosenbergii*) and "bagda," (*Penaeus monodon*), often known as "white gold" or "dollar," are significant fisheries products. 42,749 metric tons of shrimp were harvested from the sea in 2018-2019. In the 2018-2019 fiscal year, frozen shrimp and prawns earned 3088.85 crore BDT as foreign exchange (DoF, 2020).

One of the most significant current industries of Bangladesh's national economy is freshwater prawn fishing. The gigantic freshwater prawn, *M. rosenbergii*, is primarily used for aquaculture in Bangladesh's current freshwater prawn fishery. The fisheries sector has drawn much attention due to its enormous export potential. Unfortunately, since shrimp and prawns are not differentiated in the fisheries sector survey, freshwater prawn fishery statistics continue to be inconsistent, fragmentary, and frequently erroneous (Ahmed *et al.*, 2008).

Because prawns are more disease resistant than shrimp and have a higher production rate and higher profitability than other shrimp, farmers in the southwestern region of Bangladesh are gradually focusing more on prawn farming (Huque, 2007). In their shrimp and prawn farms, farmers are now more frequently involved in the unplanned and unmanaged culture of tilapia (*Oreochromis* sp.), rui (*Labeo rohita*), grass carp (*Ctenopharyngodon idella*), persa (*Planiliza persia*), and khorsula (*Rhinomugil corsula*) with prawns. However, they are ignorant of the scientific methods used to handle prawns and other species (Islam and Mahmud, 2011).

P. persia is one of the most popular and well-liked finfish among the locals because of its taste and demand. These non-carnivorous species are also easily cultivated in shrimp and prawn production zones, which are essential for maintaining healthy conditions for both shrimp/prawn and finfish (Ali *et al.*, 2000). They consume mostly debris, diatoms, algae, and minute invertebrates as filter feeders (McDonough and Wenner, 2003).

Due to its high nutritional content, consumer choice, and market price, *R. corsula*, also called the "corsula mullet" and "domra" in southern Asia and Australia, is a commercially significant fish. It is also known as the "false four-eyed fish" in tropical Americas. It is extensively dispersed across Australia, Bangladesh, Nepal, and Myanmar in the eastern Indian Ocean. *R. corsula* is an economically significant possibility for polyculture with shrimp and prawns and is simple to cultivate in shrimp and prawn growing regions (Menon, 1999; Shofiquzzoha *et al.*, 2001; Sultana, 2013). It can withstand a wide range of environmental changes and is found at depths of 10-15 m in freshwater, brackish estuaries, and marine water (Riede, 2004).

The survival rate of juveniles of *M. rosenbergii* is unaffected by finfish stocking because *P. persia* and *R. corsula* do not eat them. On the other hand, raising prawns in environmentally friendly environments may aid in increasing productivity in shrimp/prawn ponds (Shofiquzzoha and Alam, 2008). The current study was carried out to evaluate the impacts of feeds on growth, production, and financial returns in a polyculture system of *M. rosenbergii*, *P. persia*, and *R. corsula* in light of the aforementioned facts.

Materials and Methods

Study area and design: The experiment was conducted in twelve earthen ponds of brackish water in the sadar upazila of Bagerhat (Fig. 1). The average pond measured 400 m^2 in the area and ranged in depth from 0.8 to 1.6 m. The experiment lasted 120 days, from March to July 2019 and was divided into four treatments (T_1, T_2, T_3, and T_4), each of which had three replications. Ponds were chosen at random for each treatment. In all treatments, *M. rosenbergii* (prawn), *P. persia* (persa), and *R. corsula* (corsula mullet) were stocked at the same density (3:1:1).

Pond preparation and management: Ponds treated with agricultural lime ($CaCO_3$) at a rate of 250 kg ha^{-1} dependent on soil pH and gradually filled with tidal water up to a depth of 0.9 m from the adjacent tidal canal through a screen net. Rotenone at a concentration of 3 ppm was used to eradicate all undesirable species, and its effect was neutralized by lime at 125 kg ha^{-1}. Ponds were fertilized with urea and Triple Super Phosphate (TSP) at 50 and 100 kg ha^{-1}, respectively, after 5 days of cleaning. To keep out potential disease vectors like snails, snakes and others, pond dikes were covered with nylon nets with a fine mesh size.

Stocking and feed management: For all treatments, uniform-sized fingerlings of persa, corsula, and juvenile prawns were released in experimental ponds at 3 m^{-2}, 1 m^{-2}, and 1 m^{-2}, respectively. The polythene bags were held in a few selected ponds after the juvenile and fingerling prawn, persa, and corsula were collected for around 45 minutes to acclimate before being released into all the ponds. Commercial fish feed, including quality feed, mega feed, and nourish feed, was applied to the ponds six days a week at a rate of 10% of the total biomass of prawn, persa, and mullet for the first month, 6% for the second month, and subsequently fell to 3% until the end of the study.

Water quality monitoring: Temperature, salinity, transparency, dissolved oxygen (DO) concentration, pH, total alkalinity, and ammonia concentrations of the water were measured between 9.00 and 10:00 am after ten days. A portable refractometer, a standard centigrade thermometer, a Secchi disc, and a DO meter were used to test salinity, water temperature, transparency, and dissolved oxygen, respectively. A pH meter was used to record the water's pH. Titrimetric analysis was used to determine the total alkalinity. Using an ammonia test kit, ammonia nitrogen was determined.

Sampling of prawn and finfishes: The biomass of the stocked species was estimated, the feeding rations were adjusted, and physical conditions of the stocked species were also observed through a fortnightly sampling of 10-15% of the prawn, persa, and corsula. Cast nets were used to sample prawns and fish, and each species' weight and length were recorded for growth evaluation. Sampling persisted until the harvest.

Estimation of growth, survival, and production of prawn and finfishes: Water was removed from ponds after 120 days of culture, and all prawns and fish were taken by repeatedly netting them (cast net and surrounding net). Each individual was numbered, measured, and weighted to calculate the survival rate, growth, and production of each pond's harvested prawn and fish. Specific growth rate (SGR), feed conversion ratio (FCR) and survival rate (%) was calculated following the equation as cited by Pechsiri and Yakupitiyage (2005). The following are the equations:

Weight gain (g) = Mean final weight (g) **-** mean initial weight (g).

Specific growth rate (SGR) (%/day)

= {Ln (final body weight) – Ln (initial body weight) ×100}/cultured period (days).

Feed conversion ratio (FCR)

= Feed consumed (g dry weight)/live weight gain (g wet weight) of prawn/fish

Survival rate (%)

= (Number of prawn/fish harvested ÷ total number of prawn/fish stocked) × 100

Production of prawn/fish= No. of prawn/fish caught × average final weight of prawn/fish.

***Production and economic analysis*:** The following equations used to calculate production and profitability (Chowdhury *et al.* 2020, Dillon and Hardaker 1993).

Gross return (*GRi*) = Σ*iPiQi*

Net return (*π*) = Σ*i*(*PiQi*) *-TFC -TVC*

Benefit cost ratio (*BCR*) = *GRi/TC*

Here, *Pi* = market value of harvested prawn and finfish in BDT, *Qi* = production (kg ha^{-1}), *i* = treatments, *TFC* = total fixed cost, *TVC* = total variable cost and *TC* = total cost (TFC + TVC). Total net return divided by total input cost was used to calculate the benefit cost ratio (BCR). Prices for a number of inputs, including prawn, persa, and corsula, were consistent with those of the Bagerhat wholesale market in 2019. Persa and corsula were sold at rates of BDT 100.00-120.00 kg^{-1} and BDT 500.00-550.00 kg^{-1}, respectively, for prawn.

***Statistical analysis*:** The information was presented as mean and standard deviation (SD). Utilizing IBM SPSS Statistics version 23, all data were examined. Before performing a one-way analysis of variance (ANOVA), data were first evaluated for normality (Shapiro-Wilk test) and homogeneity of variance (Levene's test for equality of variance). The variance was roughly equal across the board, and all data were normally distributed. Both requirements were met, so ANOVA was used to test economic, production, and growth data. Tukey's HSD test was used to compare significant mean differences at $p < 0.05$. To determine how different feeds could predict growth metrics, linear regression was used. It was also determined how well the regression model fit the observed data using the coefficient of determination (r^2).

Results and Discussion

Growth, FCR and survival of prawn and finfishes: The prawn's final weight was highest in T_1 (72.07 g) and lowest in T_4 (50.23 g). For finfish, T_1 had the highest final weight of persa (51.03 g) and the lowest (33.84 g), whereas T_1 had the highest final weight of corsula (53.02 g) and the lowest (38.84 g) (Table 1). In a 150-day prawn and tilapia mixed culture in Bagerhat farmers' shrimp ponds, Islam *et al*. (2016) reported that the mean final weight of prawn and tilapia was 58-63 and 149-199 g, respectively. Islam and Mahmud (2012) determined the final weights of prawns and tilapia that were raised in mixed culture for 180 days at various stocking densities in the Shrimp Research Station (SRS) pond complex, Bagerhat. They pointed out that the weights were 63–73 g and 163.5–168.5 g, respectively. The final weight of prawn and tilapia in brackishwater ponds at various stocking densities for 180 days in the SRS pond complex was similarly pointed out by Islam and Mahmud (2011) to be between 74 and 85 g and 99 and 149 g, respectively. These results differ slightly from those of the most recent study. Shofiquzzoha and Alam (2008) reported the final shrimp and silver barb weights to be 23.77 and 69.75 g, respectively, after 120 days of continuous cultivation in the Brackishwater Station (BS) pond complex in Khulna. These outcomes are less favorable than those from the current investigation. The final weights of the shrimp and tilapia, measured after 120 days in the same pond complex, were 24.93 and 161.83 g, respectively. Additionally, this is lower than the most recent findings.

For 120 days, the weight gain per day for the prawn, persa, and corsula was 0.31 to 0.57, 0.27 to 0.89, and 0.31 to 0.43 g, respectively (Table 1). In shrimp ponds, the daily weight of prawn and tilapia as 0.39-0.42 and 0.99–1.33 g, respectively, by Islam *et al*. (2016). The daily weights of tilapia and prawn at various stockings were 0.35 to 0.41 and 0.91 to 0.94 g, respectively, according to Islam and Mahmud (2012). Islam and Mahmud (2011) also observed that the daily weight of prawns and tilapia in brackishwater ponds was 0.41 to 0.47 and 0.55 to 0.83 g, respectively. Shofiquzzoha and Alam (2008) stated that the daily weight of shrimp and silver barb in concurrent cultivation was 0.20 and 0.55 g, respectively, for 120 days, which is less than the current findings. In the same pond complex, they also observed the daily weights of shrimp and tilapia for 120 days as 0.21 and 1.34 g, respectively. These values are similarly lower than the current findings.

The prawn's specific growth rate (SGR) varied from 1.26 to 1.66%. On the other hand, T_1 had the highest SGR of persa (2.81%), while T_4 had the lowest (2.47%). T_1 had a greater SGR of corsula (2.80%), while T_4 had a lower SGR (2.54%) (Table 1). The ranges of shrimp SGR reported by Akter *et al*. (2019) for 120 days at Bagerhat sadar upazila of Bagerhat are higher than the results of the current study. In shrimp ponds, Islam *et al*. (2016) found that the SGR for prawn and tilapia was 1.52-1.65 and 3.98-4.13%, respectively. According to reports from Islam and Mahmud, 2012, the SGR for prawns varied between 1.71 and 1.80 and 3.13 and 3.15%, respectively. The results for prawn in the research described above are lower; however, the results for tilapia are higher than those of this study. In contrast to the present findings, Shofiquzzoha and Alam (2008) showed that the SGR of shrimp and tilapia was 6.94 and 4.26%, respectively, during 120 days.

The feed conversion ratio (FCR) of shrimp and fish was much greater in T_4 (3.7) and significantly lower in T_1 (2.40). The results of Islam *et al*. (2016), who recorded the FCR of prawn and tilapia as 2.70-3.60, are consistent with these observations. FCR changes with stocking density, feed quality, and the size at which shrimp, prawns, and fish are harvested, according to Chanratchakool *et al*. (1995). Additionally, it depends on the population dynamics and the production cycle. Depending on the quality of the additional feed and the mean weight of the prawn, shrimp, or fish as it grew, FCR increased or decreased, claims Hasan (2001). Due to the prawn and finfish's efficient utilization of the maximum ratio, T_1 in this study had the lowest FCR.

There was no statistically significant difference between T_1 and T_2, however the survival rate of prawns was substantially ($p<0.05$) higher in T_1 (54.002±52%) and T_2 (52.002±08%) than in T_3 (49.003±51%) and T_4 (41.003±06%). On the other hand, T_1 had the highest persa survival rate (58.01±53%), and T_4 had the lowest (45.002±52%). Additionally, T_1 had the highest corsula survival (52.03±06%), and T_4 had the lowest (40.002±08%). Under four treatments, a significant difference in persa and corsula survival was seen (Table 1). Similarly to this, Islam *et al*. (2016) showed that prawn and tilapia survived for 150 days at rates of 66-72 and 56.2-65.5%, respectively, while Islam and Mahmud (2012) found that prawn and tilapia survived for 180 days at rates of 62-70%, and 68-71.5%, respectively. Islam and Mahmud (2011) noted that these species had 58-65%, 67%, and 73% survival rates, respectively. The intra- and inter-specific rivalry among the stocked animals may cause the significantly reduced SGR and prawn survival seen in T_4 in the current investigation. According to Garcia-Perez *et al*. (2000), various parameters, such as environmental stress, water level, the amount of feed needed, stocking ratio, cannibalism, bird predation, predator fish, etc., affect the survival of prawns and shrimp. Cannibalism often occurs during the molting phase and may be to blame for the 4% monthly death rate (AQUACOP 1990).

Production of prawn and finfishes: T_1 had the largest prawn output (1173.27 kg ha^{-1}), whereas T_4 had the lowest (617.83 kg ha^{-1}) (Table 1). Additionally, it increased the polyculture system's overall production and financial gain from raising shrimp and fish. T_1 had a higher persa production (295.97 kg ha^{-1}), while T_4 had a lower persa production (152.28 kg ha^{-1}). T_1 produced more corsula (275.70 kg ha^{-1}) than T_2 (239.18 kg ha^{-1}), T_3 (193.80 kg ha^{-1}), and T_4 (155.36 kg ha^{-1}), respectively. This difference was statistically significant ($p<0.05$). In T_1, combined production was significantly greater (1744.94 kg ha^{-1}); in T_4, it was lower (925.46 kg ha^{-1}) ($p<0.05$) (Table 1). The combined output of prawn and tilapia was found to be 2491.80-2510.60 kg ha^{-1} in 150 days and 2191.39-2441.47 kg ha^{-1} in 150-180 days, respectively, by Islam *et al*. (2016) and Islam and Mahmud (2012). The observed production was lower. In contrast, the shrimp output reported by Islam and Mahmud (2010) and Shofiquzzoha and Alam (2008) was 416.9-641.7 kg ha^{-1} and 402.73 kg ha^{-1}, respectively, which is less than the production recorded in the current study. Because three different species were stocked, the provided feed had greater protein content, the prawn and finfish fry were larger, and the water quality was well-managed, the total production of the current study was higher than that of Islam and Mahmud (2010). According to Asaduzzaman *et al*. (2009), the combined yield of prawn and tilapia was 1,763.0 kg ha^{-1}/120 days, which is nearly identical to the current data. The highest total production, 1,691 kg ha^{-1}, was reported by Uddin *et al*. (2006) in ponds stocked with 75% tilapia and 25% prawns, which is also less than the current study.

The overall net profit from prawn and fin fish farming in the current study was significantly greater in T_1 (BDT 244694.75 ha^{-1}) and lower in T_4 (BDT 115894.42 ha^{-1})

(Fig. 2). Additionally, the benefit-cost ratio (BCR) was higher in T_1 (1.56) and lower in T_4 (1.48). The observed profit was somewhat greater than Islam *et al.* (2016)'s findings, which estimated that brackishwater ponds' prawn and tilapia aquaculture generated BDT 147, 819.00-238,923.00 ha^{-1} in profit. According to Islam and Mahmud (2011), the profit from prawn and tilapia culture ranges from BDT 137,021.00 to 236,797.00 ha^{-1}, which is also less than the results from the current study. Islam and Mahmud (2010) reported BDT 45,086.33-181,182.35 ha^{-1} as the net profit of shrimp farming, which is significantly less than the current study's findings. This shows that treating quality feed (T_1) yielded higher net profits and BCR than other methods.

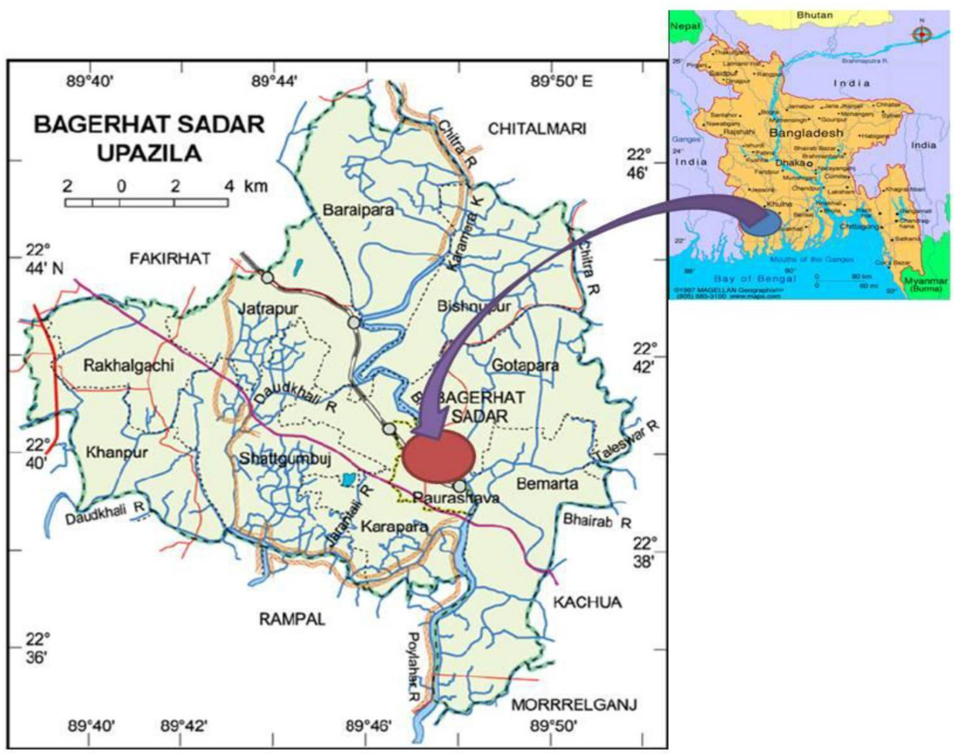

Fig.1. Map of Bagerhat sadar upazila showing the experimental area
(Source: Modified from Google Maps).

Water quality parameters: The range of the water temperature was 28.95 to 32.98°C, which is consistent with the results of Islam *et al.* (2016), and Islam and Mahmud (2012), who reported that the water temperature ranges were 27.0-32.3°C and 28.0-35.5°C, respectively. The concentration of dissolved oxygen (DO) was 4.34 to 5.25 mg l^{-1}, which is comparable to the findings of Islam *et al*. (2016), who recorded that the DO ranges from 4.0 to 5.1 mg l^{-1} in shrimp ponds.

Table 1. Growth, survival rate, and production (mean±SD) of *Macrobrachium rosenbergii*, *Planiliza persia* and *Rhinomugil corsula* in different treatments.

Parameters	Treatments			
	T_1 (Quality feed)	T_2 (Mega feed)	T_3 (Nourish feed)	T_4 (Control)
Macrobrachium rosenbergii				
Stocking density (nos. m^{-2})	3	3	3	3
Average initial weight (g)	11.01±1.38	11.05±1.16	11.11±2.30	11.21±1.78
Average final weight (g)	72.07^{a} ±2.95	70.24^{a} ±1.28	65.21^{b} ±1.25	50.23^{c} ±2.28
Daily weight gain (g)	0.57^{a} ±.0.02	0.49^{b} ±0.02	0.45^{b} ±0.02	0.32^{c} ±0.02
Specific growth rate (% day^{-1})	1.66^{a} ±0.11	1.54^{a} ±0.10	1.49^{b} ±0.16	1.26^{c} ±0.14
Survival rate (%)	54.00^{a} ±2.52	52.00^{a} ±2.08	49.00^{b} ±3.51	41.00^{c} ±3.06
Production (kg ha^{-1})	1173.27^{a} ±8.24	1095.74^{b} ±79.70	958.59^{c} ±64.74	617.83^{d} ±31.15
Planiliza persia				
Stocking density (nos. m^{-2})	1	1	1	1
Average initial weight (g)	1.75±0.04	1.75±0.03	1.75±0.03	1.75±0.04
Average final weight (g)	51.03^{a} ±1.82	47.74^{b} ±1.46	42.76^{c} ±2.72	33.84^{d} ±1.68
Daily weight gain (g)	0.41^{b} ±0.02	0.38^{b} ±0.01	0.89^{a} ±0.03	0.27^{c} ±0.01
Specific growth rate (% day^{-1})	2.81^{a} ±0.05	2.76^{b} ±0.04	2.66^{c} ±0.07	2.47^{d} ±0.05
Survival rate (%)	58.00^{a} ±1.53	53.00^{b} ±2.52	50.00^{b} ±2.65	45.00^{c} ±2.52
Production (kg ha^{-1})	295.97^{a} ±11.04	253.02^{b} ±15.09	213.80^{c} ±20.55	152.28^{d} ±11.75
Rhinomugil corsula				
Stocking density (nos. m^{-2})	1	1	1	1
Average initial weight (g)	1.83±0.03	1.83±0.05	1.83±0.04	1.83±0.04
Average final weight (g)	53.02^{a} ±5.35	50.89^{b} ±3.41	45.07^{c} ±3.73	38.84^{d} ±2.70
Daily weight gain (g)	0.43^{a} ±0.05	0.41^{b} ±0.03	0.36^{c} ±0.03	0.31^{d} ±0.02
Specific growth rate (% day^{-1})	2.80^{a} ±0.08	2.77^{b} ±0.05	2.67^{c} ±0.08	2.54^{d} ±0.07
Survival rate (%)	52.00^{a} ±3.06	47.00^{b} ±2.00	43.00^{c} ±2.65	40.00^{d} ±2.08
Production (kg ha^{-1})	275.70^{a} ±13.84	239.18^{b} ±12.63	193.80^{c} ±11.52	155.36^{d} ±14.34
FCR (all species)	2.4^{c} ±0.06	3.0^{b} ±0.15	3.5^{a} ±0.20	3.7^{a} ±0.21
Combined production (kg ha^{-1})	1744.94^{a} ± 5.52	1587.93^{b} ± 79.61	1366.18^{c} ± 93.19	925.46^{d} ± 48.83

Mean values in the same row with the same superscript letters are not significantly different ($p>0.05$).

Water salinity ranged from 3.45 to 6.97 ppt, supporting the findings of Islam *et al.* (2016), who found that shrimp ponds had water with a salinity of 1.5 to 6.5 ppt. According to Akter *et al*. (2019), which is more recent than the current investigation results, the salinity ranges for *Penaeus monodon* and tilapia ranged between 3.50 and 6.14 ppt. Ammonia nitrogen (NH_3-N) concentrations ranged from 0.002 to 0.090 mg l^{-1}, which is consistent with Meade's (1985) and Islam *et al.* (2016)'s findings that it was within an acceptable level (>0.012 mg l^{-1}) for prawn/shrimp aquaculture.

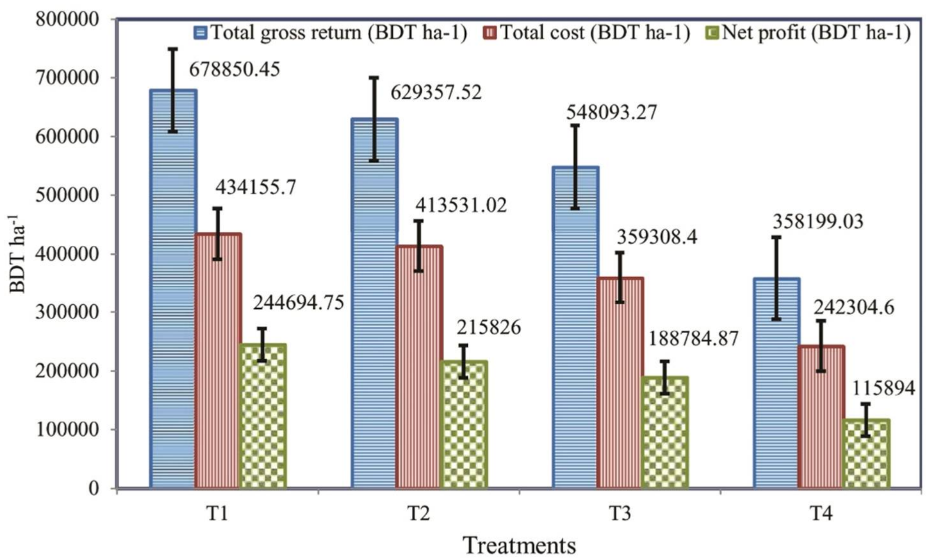

Fig.2. Cost and economic return of *M. rosenbergii, P. persia* and *R. corsula* farming during the study period.

Due to its role in increasing global prawn, shrimp, and fish production, polyculture systems are currently more popular than monoculture. The quality feed (treatment 1) is the best treatment among all treatments in terms of growth, productivity, and net profit, according to current study's findings. Finfish inclusion had no adverse effects on prawn growth or productivity. This commercial feed could be employed in prawn and finfish polyculture systems in the coastal area to increase prawn and finfish production, which would be financially rewarding, technically feasible, and socially acceptable.

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