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Research Article

INCLUSION OF RAJPUNTI (*Barbodes gonionotus*) IN TIGER SHRIMP (*Penaeus monodon*) FARMING: EFFECTS OF STOCKING RATIO OF SHRIMP AND RAJPUNTI ON PRODUCTION PERFORMANCE ALONG WITH NET RETURN

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Abstract

The study was conducted to assess the growth and production performance of shrimp and rajpunti under mixed culture at various stocking ratios in Bagerhat district over a four-month period from March to July 2023. The experiment used randomized block design (RBD) and was designed with three treatments based on stocking ratio. Shrimp *(Penaeus monodon)* post larvae and fingerlings of rajpunti *(Barbodes gonionotus)* were stocked at a ratio of 4:3, 4:5, and 4:7/m^2 in T_1, T_2, and T_3, respectively. Shrimp and rajpunti were fed commercial diets and farm-made formulated feeds on a regular basis. Different water quality parameter was measured at ten day intervals. There were no significant differences ($p > 0.05$) in water quality parameters among all treatments. Higher final weight of shrimp was found in T_2 (28.15 g) than T_1 (27.39 g) or T_3 (25.36 g). Rajpunti growth and survival rate were lower in T_3, which had a high stocking ratio. T_1 had higher shrimp production (674.34 kg/ha) than T_2 (632.44 kg/ha) and T_3 (488.24 kg/ha). Rajpunti production was substantially greater ($p < 0.05$) in T_2 (1511.10 kg/ha) and T_3 (1470.09 kg/ha) compared to T_1 (923.06 kg/ha). However, the combined output and net profit of shrimp and rajpunti farming were considerably ($p < 0.05$) greater in T_2 (2143.54 kg/ha, BDT 212309.10/ha) followed by T_3 (1958.34 kg/ha, BDT 162831.50/ha) and T_1 (1594.10 kg/ha, BDT 160845.90/ha). Therefore, the inclusion of rajpunti with shrimp at a stocking ratio of 4:5/m^2 is recommended for dissemination among shrimp farmers in order to accelerate production while also generating a high economic benefit.

Introduction

Bangladesh is one of the world's major fish producers, with a total output of 47.59 lakh MT (DoF, 2023), with aquaculture accounting for more than 57% of total production. In 2022-23, the nation alone exported 70,000 tons of fish. Bangladesh is ranked 3rd in inland open water capture production by the FAO and 5th in global aquaculture output. Geographical Indication Registration Certificate has also been obtained for tiger shrimp titled "Bangladesh Tiger Shrimp". Black tiger shrimp *(Penaeus monodon*) is the most extensively produced species in brackish water aquaculture of Bangladesh. The culture potential of shrimp *(P. monodon*) is well-established due to its strong economic production performance. Growth, output and survival of any culture species like shrimp depends on the culture system performed traditional, improved traditional, semi-intensive and intensive. Physico-chemical parameters of culture pond and their individual or synergetic influence have an essential role on the production of shrimp and pond ecology.

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Polyculture introduces a secondary or subordinate species while improving the performance of the primary cultivated species via improved water quality (Wang *et al.,* 1998; Tian *et al.,* 2001). Success of mixed culture requires correct site selection, farm design, pond preparation, stocking density, quality of feed, water exchange, disease management and production modeling. Of these, stocking ratio/density is one of the most essential parameters in aquaculture since it directly affects the survival, growth, heath, water quality, feeding and overall production of shrimp. Knowing the appropriate density for shrimp is a vital aspect for effective husbandry techniques and developing efficient culture system. Wide variations in the production of shrimp in our country are noticed due to under or overstocking. However, very little information is known in Bangladesh on the optimum stocking ratio of black tiger shrimp *(P. monodon*) and rajpunti (*B. gonionotus*).

Consecutive culture in mono-crop system in *Ghers* sometimes leads in crop loss owing to mortality problem. Crop diversification instead of mono-crop shrimp production approach may be a helpful tool in managing or diminishing shrimp mortality mainly owing to ecological and disease causes. On the other hand, culture of *P. monodon* with any acceptable short-grown fish species may help to boost up production in shrimp farms with an environment favorable scenario. Rajpunti (*B. gonionotus*) is an exotic genetically altered fish species in the country. It is a rapid growing species frequently farmed in freshwater and grow well at salinities of more than 7.0 ppt where major carps do not perform well (Ali *et al.* 2018) and it has high production potentialities (Kohinoor *et al.*, 1994). However, known to survive in a wide range of salinity 0-17 ppt (Hossain *et al.,* 1999); consume a variety of meals. It grows on relatively poor quality diet; mostly vegetable protein (Hossain *et al.,* 1994) and its fry/seed are available throughout the country.

Considering growth and production potentials, feeding behavior and economic benefits of mixed culture of rajpunti with shrimp is being conducted in several countries. However, farmers in Bangladesh could not harvest shrimp efficiently due to viral and other bacterial infections. Most of the farmers have no alternate option to accomplish their cash crop loss. So, economic loss due to sudden shrimp crop failure could be partially avoided by rajpunti crop. Considering the above facts, the present study was performed to ascertain the effects of stocking ratio of shrimp and rajpunti on total production in mixed culture.

Methodology

Study area and design

The experiment was conducted in nine brackish water shrimp ponds situated at Bagerhat sadar upazila of Bagerhat district. These ponds located between latitude 22°38'N to 22°42'N and longitude 89°44'E to 89°50'E. Average area of pond was 400 m^2 and average depth of water was 0.9-1.5 m each. Experiment was done for a period of March to July, 2023. The study was carried out following randomized block design (RBD) with three treatments (T_1, T_2, T_3) having three replications of each. Ponds were assigned at random for each treatment. Shrimp and rajpunti stocking ratio in T_1, T_2, and T_3 were 4:3, 4:5, and 4:7/m^2, respectively.

Pond preparation and management

All ponds were prepared by repairing the embankments and removing vegetation. Before the study, ponds were treated with agricultural lime ($CaCO_3$) at a rate of 250 kg/ha, depending on soil pH. Ponds were then progressively filled with tidal water from the adjacent tidal canal, up to a depth of 0.9 m, using a screen net. Rotenone at a rate of 3 ppm was used to remove all unwanted species, followed by 125 kg/ha of lime ($CaCO_3$) to neutralize its toxic activity (lime neutralizes the toxic activity of rotenone primarily by raising the pH and facilitating the breakdown of the rotenone compound, and making the water safer for stocked species). Following 5 days of cleaning, ponds were fertilized with urea and TSP at rates of 50 and 100 kg/ha, respectively. After 4-5 days of fertilization, water became green. Fine mesh nylon net was used as a fence around ponds to remove possible disease carriers, such snails, snakes and others from outside.

Stocking of shrimp and rajpunti

Shrimp PL were stocked in all ponds at a rate of 4 per square meter. After 25 days, shrimp PL and rajpunti fingerlings were supplied in all ponds. Rajpunti were stocked at 3, 5, and 7 per square meter in T_1, T_2, and T_3, respectively. Initial weight and length of 30% of each were recorded independently before released into ponds using a portable digital balance (CAMRY digital electrical balance, EK 3052, Bangladesh) and a measuring scale, respectively.

Post−stocking management

Commercial pelleted shrimp feed (with 32.0% protein, 11.0% moisture, 5.0% crude lipid and 8.0% crude fiber level) purchased from local market was applied to ponds six days a week at a rate of 10% of shrimp biomass for the first month, 6% for the second month, and gradually decreased to 3% by the end of the study. Rajpunti were fed with farm-made feed (40% rice bran, 20% wheat flour, 15% maize flour, 20% fish meal and 5% mustard oil cake) thrice a day at a rate of 10% of total biomass for first two months and 5% of body weight at the conclusion of culture period. Daily feed was divided into three equal parts: 8.00-9.00 am in the morning, 12.00-1.00 pm at midday and 5.00-6.00 pm in the evening to optimize feed utilization and reduce competition among farmed species. Rajpunti feed was employed prior to shrimp feed application (30-45 minutes). Lime was applied to all of ponds on a monthly basis at a rate of 50.0-75.0 kg/ha dependent on water depth to maintain optimum water quality. Dried coconut leaves, palm leaves, jute bags and bamboo kanchi (branches of bamboo) were laid on the pond's bottom to provide protection for shrimp and fish while keeping the water cool.

Water quality monitoring

Water parameters in ponds, including temperature, salinity, DO concentration, pH, total alkalinity, and ammonia were measured at ten day intervals between 9.00 and 10.00 am. Salinity of water was tested using a portable refractometer (ATAGO, Hand Refractometer). Temperature of surface water was measured in situ using a standard centigrade thermometer. Secchi discs were used to measure transparency. Dissolved oxygen was measured using a portable DO meter (YSI 58 digital DO meter, HANNA, Yellow Springs, Ohio 45387 USA). pH of water was measured using a pH meter (HANNA, USA). Total alkalinity was determined using the titrimetric approach (APHA, 2000). Ammonia nitrogen was measured using an ammonia test kit (Biosol, A.A. Biotech PVT Ltd, and Fishtech BD Ltd).

Sampling of shrimp and rajpunti

Fortnightly sampling of 10-15% of stocked shrimp and rajpunti was done to determine the biomass and to adjust the feeding rations and also to examine the physical condition of stocked species. Shrimp and rajpunti were sampled using cast net. Weight and length of 30 individuals of each species were recorded for growth assessment. Weight (g) and length (cm) were measured using a portable balance and measuring scale, respectively. Sampling was continued till harvesting.

Harvesting and production parameters

After 120 days of culture, bamboo poles and leaves were removed, water was drained out of ponds and all shrimp and rajpunti were harvested by repeated netting (cast net and surrounding net). All rajpunti and shrimp harvested from each pond were counted, measured and weighted individually. Status of growth, feed utilization, yield like 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 shrimp), survival rate (%) = (number of shrimp/fish harvested ÷ total number of shrimp/fish stocked) × 100) and production of shrimp = (number of shrimp harvested × average final weight of shrimp) were calculated.

Economic analysis

A simple algebraic economic analysis was carried out to calculate net return and benefit cost ratio of shrimp and fish culture in different treatments. The following equation was used to assess the profitability of shrimp and rajpunti production in pond systems: NR = TR – TC (FC + VC + Ii).

Where NR = net return, TR = total revenue from shrimp and rajpunti sales, TC= total cost, FC = fixed/common costs, VC = variable costs and Ii = interest on inputs. Benefit cost ratio (BCR) was determined as total net return/total input cost.

Prices of different kinds of inputs, shrimp and rajpunti correspond to Bagerhat wholesale market pricing in 2023. Shrimp and rajpunti were sold at a rate of BDT/kg 530.00−560.00 and BDT/kg 140.00−180.00, respectively.

Statistical analysis

Data was collected, documented, compiled and saved for statistical analysis. Growth, production, net returns and benefit cost ratio were analyzed using a one-way ANOVA for testing the homogeneity of variance, followed by Tukey-HSD to identify the differences among treatments. All ANOVA were tested at 5% level of significance using SPSS (Statistical Package for Social Science) version 20.

Results and Discussion

Growth and production performance of shrimp and rajpunti

Production of shrimp and rajpunti in all treatments observed variations among treatments due to difference of survival, growth rate and feed utilization. All scenario of the study are depicted in Table 1.

Table 1. Growth, survival rate and production of *Penaeus monodon* and *Barbodes gonionotus* in different treatments for 120 days

Species and production parameters	Treatments		
	T_1 (4:3/m^2)	T_2 (4:5/m^2)	T_3 (4:7/m^2)
	Penaeus monodon		
Average initial weight (g)	0.006 ± 0.002^a	0.006 ± 0.002^a	0.006 ± 0.002^a
Average final weight (g)	27.39 ± 2.08^{ab}	28.15 ± 3.79^a	25.36 ± 2.80^b
Daily weight gain (g)	0.23 ± 0.02^a	0.23 ± 0.03^a	0.21 ± 0.02^a
Survival rate (%)	79.00 ± 2.64^a	72.66 ± 3.50^{ab}	62.33 ± 3.51^b
Specific growth rate (%/day)	7.01 ± 0.13^a	7.12 ± 0.30^a	6.99 ± 0.13^a
Production (kg/ha)	674.34 ± 25.75^a	632.44 ± 96.66^a	488.24 ± 66.37^b
	Barbodes gonionotus		
Average initial weight (g)	1.0 ± 0.02	1.0 ± 0.04	1.0 ± 0.03
Average final weight (g)	134.26 ± 6.29^a	120.07 ± 3.28^b	94.91 ± 3.08^c
Daily weight gain (g)	1.11 ± 0.05^a	1.00 ± 0.03^b	0.79 ± 0.03^c
Survival rate (%)	69.00 ± 3.00^a	63.33 ± 1.52^b	52.00 ± 2.00^c
Specific growth rate (%/day)	4.08 ± 0.04^a	4.00 ± 0.05^a	3.80 ± 0.02^b
Production (kg/ha)	923.06 ± 1.42^b	1511.10 ± 19.88^a	1470.09 ± 86.94^a
Combined production (kg/ha)	1594.1 ± 20.50^c	2143.54 ± 99.66^a	1958.34 ± 152.93^b

Mean values in the same row with same superscript letters are not significantly different ($p > 0.05$). All values are expressed as mean ± SD (n=3).

Mean final shrimp weight was maximum in T_2 (28.15 g), followed by T_1 (27.39 g) and T_3 (25.36 g). In case of rajpunti, T_1 had the highest final weight (134.26 g) compared to T_2 (120.07 g) and T_3 (94.91 g) (Table 1). Jahan *et al.* (2021) showed that mean final weight of prawns and fin fish ranged from 38.0 to 43.0 and 118.0 to 125.0 g, respectively. Islam *et al.* (2016) found that after 150 days of mixed culture in Bagerhat prawn ponds, average final weight of prawns and tilapias was 58-63 and 149-199 g, respectively.

Daily weight gain of shrimp and rajpunti was gained 0.21-0.23 and 0.79-1.11 g per day over 120 days, respectively. Jahan *et al.* (2021) found that daily weight gain for shrimp and fin of fish was 0.29-0.33 g and 0.95-1.01 g, respectively. Islam *et al.* (2016) found that shrimp and tilapia weight of 0.39-0.42 and 0.99-1.33 g per day in Bagerhat farmers' prawn ponds. Islam and Mahmud (2012) measured daily prawn and tilapia weights of 0.35−0.41 and 0.91−0.94 g, respectively, at varied stocking densities in the SRS pond complex, Bagerhat.

Feed conversion ratio (FCR) for rajpunti and shrimp ranged from 2.42 to 3.48. The results of the current study are in line with those of Islam *et al.* (2016), who reported that the FCR of tilapia and prawn was 2.70−3.60. Islam and Mahmud (2012) found that FCR of tilapia and shrimp was 2.80−3.50. According to Islam and Mahmud (2011), FCR for tilapia and prawns was 2.90−3.45. Islam and Mahmud (2010) stated that FCR for shrimp was between 2.5 and 3.7. These outcomes more or less align with the results of recent studies.

Survival rate of shrimp and rajpunti were 62.33-79.0 and 52-69%, respectively. Jahan *et al.* (2021) showed that shrimp and fin fishes have survival rates of 57.0-74.0 and 61.0-69.0%, respectively. Shrimp growth and survival rates were seen to decline when stocking ratio increased. Water depth and pond space were also shown to influence survival and growth rates. Current study found considerable difference in survival rates of rajpunti species among three treatments, which might be caused by intra and inter-specific competition among the stocks. According to Garcia-Perez *et al.* (2000), several factors influence shrimp and fish survival, including environmental stress, water level, dietary requirements, stocking ratio, cannibalism, bird predation, predatory fish and so on. Islam *et al.* (2016) found that prawn and tilapia survival rates were 66-72 and 56.2-65.5%, respectively, after 150 days of mixed culture in Bagerhat farmers' prawn ponds. Islam and Mahmud (2011) found that shrimp and tilapia had survival rates of 58–65% and 66–73%, respectively. These findings are very similar to current findings. Islam and Mahmud (2010) reported a shrimp survival rate of 58-72.5%, which is lower than current findings.

Specific growth rate (SGR) of shrimp and rajpunti ranged from 6.99-7.12 and 3.80-4.08%, respectively. Jahan *et al.* (2021) calculated SGR of shrimp and fin fishes to be 2.12-2.22 and 2.72-2.87%, respectively. Islam *et al.* (2016) found prawn and tilapia SGR of 1.52-1.65 and 3.98-4.13% in farmers' ponds. Islam and Mahmud (2012) found that prawn and tilapia had SGR of 1.71−1.80 and 3.13−3.15%, respectively, at varied stocking densities in Bagerhat's SRS pond. These findings are lower than those of current study. Shofiquzzoha and Alam (2008) found that SGR of shrimp and silver barb was 6.90 and 2.56%, respectively, in concurrent culture for 120 days at BS pond complex in Khulna, which is lower than current results. They also reported SGR of shrimp and tilapia at 6.94 and 4.26%, respectively, for 120 days in same pond complex, which is compatible with the findings of current study.

Shrimp PL and fish seed utilized in this culture system were obtained from a variety of suppliers at varying costs. Every farm has a variable stocking ratio/density based on finances and area/location. In data envelopment analysis, fry/seed was quantified as the total number of PL/fingerlings per crop. Relation between amount of feed used and production were shown in Figure 1. These coefficients of determinants are very high (R^2 is 0.9206). This indicates that the relation between quantity of feed used and production is strongly close. Figure 2 shows the relationship between production and shrimp PL/fingerlings/fry that used. It explained that production and fish fry/seed used has close relationship.

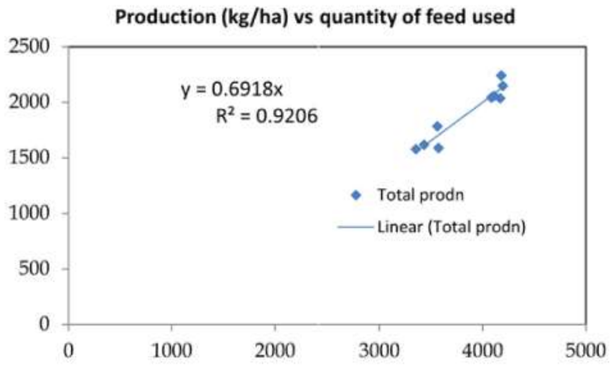

Figure 1. Regression between production and used feed quantity.

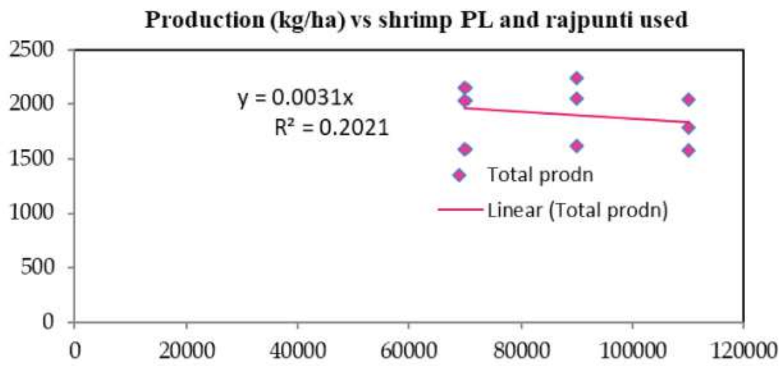

Figure 2. Regression between production and shrimp & rajpunti seeds.

Production of shrimp and rajpunti

Shrimp and rajpunti production in all treatments varied from 488.24 to 674.34 and 923.06 to 1511.10 kg/ha, respectively. Combined yield of shrimp and rajpunti ranged from 1594.01 to 2143.54 kg/ha, with T_2 producing the most (2143.54 kg/ha) and T_1 producing the least (1594.01 kg/ha) throughout a 120-day culture period (Figure 3). It was shown that T_1 had a lower shrimp-rajpunti ratio and total quantity of shrimp-rajpunti than the other two treatments, resulting in increased growth, survival, and output of the grown species. Overall output was higher in T_2 than in T_1 or T_3. This might be due to a well-balanced shrimp-rajpunti ratio, as well as optimal feed and pond space utilization. Growth rates often rise when stocking density drops, and vice versa. Having fewer fish of equivalent size in a pond allows for greater space, food, and dissolved oxygen (Mollah *et al.,* 2011). The observed production was lower than that of Islam *et al.* (2016) and Islam and Mahmud (2012), who recorded combined production of prawn and tilapia as 2491.80-2510.60 kg/ha/150 days and 2191.39-2441.47 kg/ha/150-180 days, respectively, in farmers' prawn ponds and SRS pond complex, Bagerhat. Current study's findings are comparatively higher than those of Islam and Mahmud (2011), who obtained 1105.0–2133.4 kg/ha/180 days in SRS pond complex. Islam and Mahmud (2010) found that shrimp output in farmers' farms ranged from 416.9 to 641.7 kg/ha, which is lower than current study's results. Shofiquzzoha and Alam (2008) reported that production of shrimp and silver barb was 136.77 and 402.73 kg/ha, respectively, and production of shrimp and tilapia was 162.13 and 1272.95 kg/ha, respectively, in concurrent culture for 120 days at BS pond complex in Khulna, which is also lower than present findings.

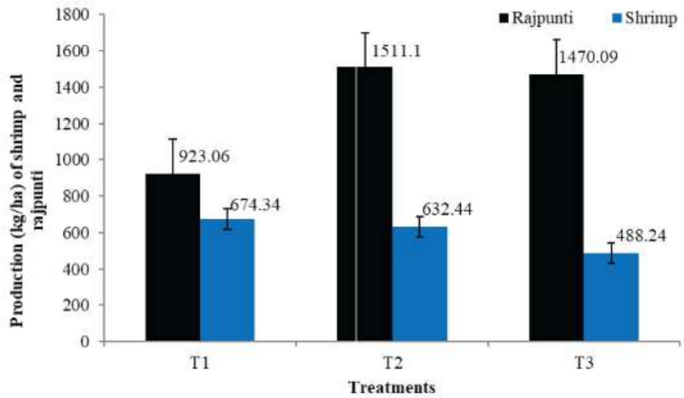

Figure 3. Production (kg/ha) of *P. monodon* and *B. gonionotus* in three treatments.

Profit of shrimp and rajpunti culture

In current study, T_2 (BDT 212309.10/ha) had the greatest profit from shrimp and rajpunti farming followed by T_3 (BDT 162831.50/ha) and T_1 (BDT 160845.90/ha) (Figure 4). Cause of T_2 had a higher output than others. T_2 also had a better overall return. As a result, T_2 had a greater net profit than other treatments. T_2 had a greater benefit-cost ratio (BCR) (1.66) than T_3 (1.57) and T_1 (1.49). The observed profit was slightly lower than that of Jahan *et al.* (2021), who found profit of prawn and fin fishes to be BDT 179393.31-277384.51/ha. Islam *et al.* (2016) found that prawn and tilapia farming yielded a profit of BDT 147819.00−238923.00/ha in farmers' ponds, which is similar to current findings. Islam and Mahmud (2011) found that profit from prawn and tilapia production ranged from BDT 137021.00 to 236797.00/ha at SRS pond complex, which is close to the findings of this study. Islam and Mahmud (2010) concluded that net profit of shrimp farming in Bagerhat farmers' farms for 120 days using commercial and BFRI feeds was BDT 45086.33-181182.35, which is lower than current study's findings.

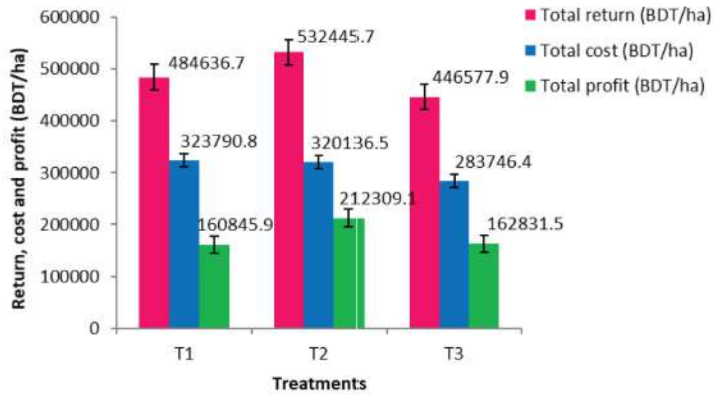

Figure 4. Cost and economic return of shrimp and rajpunti farming in three different treatments.

Water parameters of culture ponds

Water quality parameters from different ponds under different treatments like as water temperature, transparency, dissolved oxygen, salinity, pH, total alkalinity and ammonia nitrogen were measured every ten day intervals. In this research, water temperature ranged from 26.49 to 32.99°C which are consistent with those of Jahan *et al.* (2021) and Akter *et al.* (2019), who determined that the temperature varies of 27.61 to

33.2°C and 26.39 to 32.97°C, respectively. Water transparency in all treatments ranged from 29.12 to 36.84 cm. These results are comparable to those of Jahan *et al.* (2021), who discovered that water transparency ranged from 28.78 to 36.97 cm. Dissolved oxygen (DO) values ranged from 4.32 to 5.38 mg/l, that supporting the outcomes of Jahan *et al.* (2021) and Islam *et al.* (2016), they observed DO values of 4.15 to 5.28 mg/l and 4.0 to 5.1 mg/l, respectively. Salinity of all treatments ranged from 3.48 to 6.12 ppt which consistent with those of Jahan *et al.* (2021) and Islam *et al.* (2016), they measured salinity of the water ranging from 3.47 to 6.44 ppt and 1.5 to 6.5 ppt, respectively. pH ranged from 6.66 to 7.35 in all treatments, which is nearly same to the findings of Jahan *et al.* (2021) and Islam *et al.* (2016), who observed water pH ranges of 6.55 to 7.36 and 7.1 to 7.7, respectively. Total alkalinity varied from 90.52 to 103.36 mg/l which was very close to the Jahan *et al.* (2021) and Islam *et al.* (2016), who showed that total alkalinity in shrimp ponds ranged from 92.33 to 101.15 and 90.0 to 106.5 mg/l, respectively. Ammonia nitrogen concentrations in all treatments ranged from 0.005 to 0.093 mg/l, which is similar to the results of Jahan *et al.* (2021) and Islam *et al.* (2016), they observed that ammonia nitrogen ranges in Bagerhat farmers' shrimp ponds are from 0.008 to 0.097 and 0.002 to 0.092 mg/l, respectively.

Conclusion

Mixed/Polyculture has grown in importance over monoculture across the world since it helps to boost total productivity. According to findings of current study, stocking ratio of fish affected the economic return positively. There was no adverse change in water quality due to the different ratio of fishes. Further, inclusion of fish did not hamper the growth and production of shrimp. As a result, cost and economic return of the study suggest that mixed culture of shrimp and rajpunti at a stocking ratio of 4:5/m^2 might be a very profitable aquaculture approach in Bangladesh's coastal areas.

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