Turkish Journal of Fisheries and Aquatic Sciences 8: 15-23 (2008)

Effect of Inclusion of Prawn and Mola on Water Quality and Rice Production in Prawn-Fish-Rice Culture System

AKM. Rohul Amin[1,]*, M. Salauddin[2]
[1] Bangladesh Agricultural University, Department of Aquaculture, Mymensingh, Bangladesh.
[2] Hajee Mohammad Danesh Science and Technology University, Department of Fisheries Biology and Genetics, Dinajpur, Bangladesh.

* Corresponding Author: Tel.: +91.342 2657595
E-mail: akm_ramin@yahoo.com

Received 16 May 2007
Accepted 25 December 2007

Abstract

A long term experiment for a period of sixteen weeks was conducted from August to November, 2005 to observe the effects of inclusion of prawn (*Macrobrachium rosenbergii*) and mola (*Amblypharyngodon mola*) on water quality and rice production. To achieve the target, four treatments each with three replications were set in the experiment. In all treatments, prawn was stocked with mola in the rice field. The stocking densities of prawn were 10,000, 15,000, 20,000 and 25,000/ha in treatments T_1, T_2, T_3 and T_4 respectively. The stocking density of mola was 20,000/ha in all the treatments. All rice plots were fertilized with urea (200 kg/ha), TSP (150 kg/ha) and MP (75 kg/ha). The mean values of water quality parameters such as temperature, transparency, dissolved oxygen, pH, alkalinity, ammonia, nitrate-nitrogen, phosphate-phosphorus and chlorophyll-a in all the plots showed very small variations among the different treatments except chlorophyll-a which was relatively higher in all treatments. All the parameters were found within the suitable ranges for prawn and mola culture and with respect to cultural suitability, prawn performed comparatively higher growth rate and survival rate in treatment $T_{2,}$ where stocking density was 15,000 kg/ha. The highest production (456.16 kg/ha) of prawn was also recorded in the treatment-T_2 compared to other treatments. The yields of rice grain recorded were 3.71 mt/ha, 2.88 mt/ha, 3.33 mt/ha and 3.04 mt/ha in $T_{1,}$ $T_{2,}$ T_3 and T_4, respectively. The highest yield of rice grain obtained was 3.71 mt/ha in treatment-1. The study provided evidence that the introduction of prawn and mola in rice fields has profound impacts on the availability of nutrients in the water and soil which ultimately increases the yield of rice grain and straw and at the same time provides an additional yield of prawn and mola from the same land and ultimately the rural poor farmers would benefit economically and nutritionally by adopting rice-prawn-mola integrated culture system.

Key words: integration, fresh water, *Macrobrachium rosenbergii, Amblypharyngodon mola*, rural farmer.

Introduction

Rice and fish dominate the diet of Bangladeshis to such an extent that the old proverb, "machee bhatee bangali" which can be translated as 'fish and rice make a Bangali' continues to hold true. Fish and prawn are two essential food items through out the world. Most of the freshwater prawn species, especially *Macrobrachium rosenbergii*, have wide ranges of environmental tolerance. *M. rosenbergii* can grow well in freshwater to saline water up to 15‰ and up to 2–5‰ in cages, in ponds and in a wide range of temperatures. There are about 125 species of freshwater prawn in the world, of which 49 are known as commercially important (Hossain, 1995). In Bangladesh there are about 23 species of freshwater prawn including 10 species of *Macrobrachium* spp. (Akand and Hasan, 1992). Of these, giant freshwater prawn *Macrobrachium rosenbergii*, and monsoon river prawn, *Macrobrachium malcolmsonii*, are the two commercially important species. The prawn industry supports a thriving local economy and generates important foreign exchange earnings for the country and many people's livelihoods depend on the prawn industry (Williams and Khan, 2003). The country has a vast potential of integrating fish and prawn culture with rice farming. The basic principles involved in integrated farming are the utilization of the synergetic effects of integrated farming activities and the conservation including the full utilization of farm waste. It is based on the concept that "there is no waste" and waste is only a misplaced resources which can become a valuable material for another product (FAO, 1977).

Bangladesh has more than 2.83 million ha of seasonal paddy fields where water remains and planted to traditional rice (Karim, 1978). Integrated rice-prawn-fish farming is probably the best example of integration where rice and fish/prawn are directly benefited by each other. Fish activities in the rice fields enhance the fertility and environment of rice fields and as a result, rice yield is increased by 10-15% with very few exceptions (Hora and Pillay, 1962; Khoo and Tan, 1980; Zhang, 1986; Li, 1988; dela Cruz *et al.,* 1992; Kamp and Gregory, 1993). Lightfoot *et al.* (1990) stated that the integrated rice-fish farming offers possibilities of increasing rice yields by as much as 15% and at the same time harvesting up to 500 kg/ha of fish in every rice crop. If 5% of the rice field in Bangladesh could be brought under rice fish culture, about 76,000 tons of fish will be produced per year assuming a conservative fish production of 150 kg/ha/year. This would be equivalent to 6.5% increase in the present total fish production of Bangladesh (BBS, 1998). Prawn culture in rice fields provides not only an additional income from the yield of fish, but also improves the yield of rice (Arce and dela Cruz, 1979; Li, 1988; Lightfoot *et al*., 1990; Halwart, 1994). Introduction of fish into the rice fields in a managed way has a number of advantages, such as it helps in increasing yield of rice by feeding on harmful insects, pests and weeds (Coche, 1967) and increase the farm fertility by adding organic excreta. It raises the profit per unit area of land one or two folds. It is argued that rice-fish/prawn culture can be used as a tool in Integrated Pest Management (IPM) as insecticide application on pest resistance rice varieties is largely uneconomical. In this technology, as a "do not spray" strategy could be changed to a more attractive strategy "grow fish" (Weibel, 1992).

Among the Small Indigenous Species (SIS) of fish, mola (*Amblypharyngodon mola*) is a most demandable and delicious small indigenous fish to the people of Bangladesh. Mola is particularly important for its high content of vitamin-A than any other edible fish (Ahmed, 1981). A medium size mola fish has about 2.0 g of edible protein in its body, which contain 520 IU of vitamin-A. This means that intake of only three mola fish daily would contribute to more than 1500 IU of vitamin-A, which is sufficient to save a child from blindness, caused by vitamin-A deficiency (BSS, 1998). In 100 g of mola, the vitamin-A, calcium and iron contents are approximately 1960 mg, 1071 mg and 7.0 mg, respectively (Thilsted *et al*., 1997). Nutrition surveys conducted in Bangladesh revealed that there has been high prevalence of vitamin-A deficiency in rural population especially among the pre-school children. About 75% of the rural children in Bangladesh suffer from malnutrition and 25% of them below 5 years of age die due to malnutrition (Ahmed and Hassan, 1983). Human nutritionists claimed that small indigenous fish species especially mola can play a major role in the elimination of malnutrition as well as night blindness in rural Bangladesh.

Anyway, much more research and extension work has not yet been carried out on prawn and mola culture which are very nutritious and delicious food items. The rice fields may be the most suitable habitats for culture of prawn with mola which will play an important role in the economy of Bangladesh in terms of nutrition, income, employment generation and foreign exchange earning. In the above context, the present study has been undertaken to achieve the following objectives:

i) To observe the impacts of the introduction of prawn and mola in rice fields
ii) To determine the variation of water quality parameters in prawn-fish- rice culture system

Materials and Methods

This experiment was carried out at the Dahuki village of Gouripur upazilla in Mymensingh district. There were 12 experimental farmers plots with different size and rectangular in shape. Rainwater was the source of water. Embankments (1.0 m height and 0.50 m width) were made surrounding the experimental areas, which made the plots free from flood. The experiment was designed in randomized block design (RBD) with four treatments such as T_1, T_2, T_3 and T_4 with three replications that are R1, R_2 and R_3. Prawn was stocked with mola in treatments T_1, T_2, T_3 and T_4. The stocking density of prawn were 10,000, 15,000, 20,000 and 25,000/ha in T_1, T_2, T_3 and T_4, respectively and the stocking density of mola was the same (20,000/ha) in all the treatments.

All the experimental plots were prepared well and fertilized with urea, triple super phosphate (TSP) and murate of potash (MP) at the rate of 200 kg/ha, 150 kg/ha and 75 kg/ha, respectively as recommended by BRRI (1999). In rice-fish culture system high yielding varieties (HYV) which have medium height, resistant to insects, diseases and require less growing time (105-125 days) than the most local varieties (160 days) are recommended for rice-fish culture (Singh *et al*., 1980; dela Cruz *et al*., 1992). For this purpose BR-22 was selected for the experiment. Seeds of BR-22 were incubated for 48 hours after soaking in water for 24 hours. Sprouted seeds were then sown on a well-prepared wet seedbed. The rice seedlings were transplanted in the experimental plots. Alternate row spacing of 35 cm and 15 cm was followed in the experiment for transplanting rice seedling, which is recommended by Hossain *et al.* (1990). The plant to plant distance given was 20 cm. The alternate row spacing would provide enough space for easy movement of fishes and sunlight to fall on water between the rows and improve the yield of plankton, fish and rice. The juvenile of prawn were collected from local private nursery and stocked properly after conditioning. Fry of mola were collected from local private nursery and stocked properly. The small mola and prawn juveniles were released in the experimental plots 27 and 30 days, respectively after transplanting of rice seedlings. For proper management of rice, all the activities were done according to the recommendation of Farming System and Environmental Studies (FSES) of Bangladesh Agricultural University, Mymensingh. Use of low-cost supplementary feed, water supply and observation of fish health were done for fish management. The health condition of mola and prawn were observed at every 30 days after fry releasing by decreasing the water level of the experimental plot. Pelleted feed was supplied once daily at the rate of 3-8% of body weight of prawn.

During the study period, the status of physicochemical parameters of water like temperature, transparency, dissolved oxygen, pH, alkalinity, ammonia, nitrate-nitrogen, phosphate-phosphorus and chlorophyll-a were recorded fortnightly. Water temperature, transparency, dissolved oxygen and water pH were recorded directly in the field with the help of a Celsius thermometer, secchi disc, a digital electronic DO meter (YSI, Model 58) and an electrical pH meter (JENWAY, Model 3020). The concentration of nitrate-nitrogen (mg/L), ammonia (mg/L), alkalinity (mg/L) and phosphate-phosphorus (mg/L) of water samples were determined in the laboratory after filtering the water samples taken from rice field by using spectrophotometer (HACK DR 2000) and reagent of mineral stabilizer, polyvinyl alcohol, nessler, 0.2 N sulphuric acid, methyl orange, pillow nitrover-3 and phosver-3, respectively. Chlorophyll-a (µg/L) was measured from the filter papers (Whatman GF/C) used for filtering the water samples. The filter papers were dissolved in 10 ml acetone and kept overnight, then centrifuged and made ready for the analysis of Chlorophyll-a. Later, Chlorophyll-a was determined by using a spectrophotometer (Milton Roy Spectronic, Model 1001) at 664 and 750 nm wavelengths. The rice was harvested after 132 days of transplanting seedling by cutting the plants at the ground level with sickle. The representative samples of rice were taken from each plot comprising an area of 1 m^2 randomly. It was then threshed with a pedal thresher. The grains were then cleaned and sun dried for three days to 14% moisture content. The straws were also sun dried. The weights of dried grain and straw were taken (kg/m^2) and recorded separately for each plot. These were then converted to metric ton per hectare (mt/ha). The mola and prawn were harvested immediately after harvesting of rice i.e. after 120 days of stocking of small mola and juvenile prawns. The fish and prawns were collected from each experimental plot by hand picking after draining out water from the plots. The collected fish and prawns from the plots were counted and the number was recorded separately. The total length (cm) and weight (g) of 30 fish of each species and prawn were taken randomly without any bias from each plot to determine the survival rate, growth and yield of fish and prawns. To estimate the growth, total length (cm) and weight (g) of individual mola and prawn were recorded separately plot-wise during stocking period and final harvesting period. The length and weight of mola and prawn were recorded separately with the help of measuring scale and a portable sensitive electronic balance (Model OHAUS CT1200-S). Growth of mola and prawn was determined by the following ways:

a) Length gained = Mean final length – Mean initial length

b) Weight gained = Mean final weight–Mean initial weight

c) % of weight gained = (weight gained/Initial weight)x100

d) % of length gained = (Length gained/Initial Length)x100

e) Survival rate (%) = (No of fish cought/No of fish released) x 100

f) Yield of fish/prawns

I. Gross Yield = No of fish caught × Average final weight
II. Net Yield = No of fish caught × Average weight gained

g) SGR (%/day) = [(Ln Final wet weight-Ln Initial wet weight)/days] x100

All the data collected during the experiment were recorded and preserved in computer. The data obtained in the experiment were analysed statistically using analysis of variance (ANOVA). The mean values were compared to Duncan's Multiple Range Test (Gomez and Gomez, 1984 and Zar, 1974).

All the data collected during the experiment were recorded and saved in computer. The data obtained in the experiment were statistically analysed using analysis of variance (ANOVA). The mean values were compared to Duncan's Multiple Range Test (Gomez and Gomez, 1984; Zar, 1974).

Results

Water Quality Parameters in Rice Fields

The values of water quality parameters of rice fields of four different treatments are in Table 1.

Temperature: In the study period, the average water temperature recorded varied from 24.93-34.33°C in rice plots. Temperature showed fortnightly variations in all the treatments with more or less continuous decreasing trend towards the end of the experiment (Figure 1).

Transparency (cm): During the study period, the average recorded transparency was varied from 20.33–37.67 cm in rice the plots. The highest value of water transparency (37.67 cm) was recorded in T_1 and T_4 and the lowest (20.33 cm) was recorded in T_1. The values of transparency showed remarkable fortnightly variations among the four treatments in the experiment (Figure 2).

Dissolved Oxygen (mg/L): During the experiment, average dissolved oxygen recorded varied from 3.02-7.31 mg/L in rice plots. The highest value of dissolved oxygen content (7.31 mg/L) was found in T_2 and the lowest (3.02 mg/L) was found in T_1. However, the values of dissolved oxygen content recorded in different treatments showed little variations from time to time (Figure 3).

Water pH: During the study period, the average pH recorded varied from 6.97-8.63 in rice plots. The highest pH value (8.63) was recorded in T_2 and the lowest (6.97) was recorded in T_3. The values of pH showed remarkable fortnightly variations among the four treatments in the experiment (Figure 4).

Chlorophyll-a (µg/L): The average chlorophyll-a recorded varied from 5.14-286.79 µg/L in rice plots.

Table 1. Mean values (±S.E.) and range of water quality parameters

Parameters	Treatment–I	Treatment–II	Treatment–III	Treatment–IV
Temperature (°C)	29.89±1.01[a] (25.4–34.03)	30.11±1.09[a] (24.93–33.43)	30.06±1.07[a] (24.93–33.43)	30.47±1.16[a] (25.33–34.33)
Transparency (cm)	25.74±1.91[b] (20.33–37.67)	28.52±1.10[ab] (23.67–34.33)	28.11±0.92[ab] (24.67–32.67)	30.74±1.44[a] (24.33–37.67)
DO (mg/L)	4.75±0.32 [a] (3.02–5.71)	5.36±0.32[a] (4.35–7.31)	5.44±0.33[a] (4.30–7.11)	5.29±0.22[a] (4.14–6.30)
pH	7.61±0.09[a] (7.07–7.97)	7.89±0.12[a] (7.40–8.63)	7.67±0.11[a] (6.97–8.10)	7.72±0.07[a] (7.30–8.07)
Chlorophyll–a (μg/L)	113.71±14.96[a] (48.79–176.52)	101.58±16.05[a] (29.75–170.57)	121.47±27.30[a] (15.87–286.79)	81.48±13.96[a] (5.14–150.73)
Alkalinity (mg/L)	56.52±5.29[a] (30.0–83.0)	61.78±6.93[a] (36.0–100.0)	57.19±5.47[a] (37.0–86.0)	60.59±6.92[a] (37.0–96.0)
NH_3 (mg/L)	0.24±0.052[a] (0.05–0.51)	0.19±0.029[a] (0.03–0.29)	0.27±0.103[a] (0.09–1.09)	0.25±0.037[a] (0.07–0.44)
PO_4 (mg/L)	0.227±0.075[a] (0.05–0.81)	0.330±0.069[a] (0.04–0.73)	0.261±0.079[a] (0.08–0.87)	0.160±0.032[a] (0.05–0.35)
NO_3 (mg/L)	0.120±0.083[a] (0.09–0.17)	0.138±0.015[a] (0.05–0.21)	0.128±0.019[a] (0.07–0.20)	0.133±0.015[a] (0.06–0.22)
No_2 (mg/L)	0.019±0.006[a] (0.007–0.062)	0.022±0.003[a] (0.012–0.040)	0.016±0.0021[a] (0.007–0.024)	0.018±0.002[a] (0.011–0.033)

Mean values with different superscripts in the row were significantly different (P<0.05)

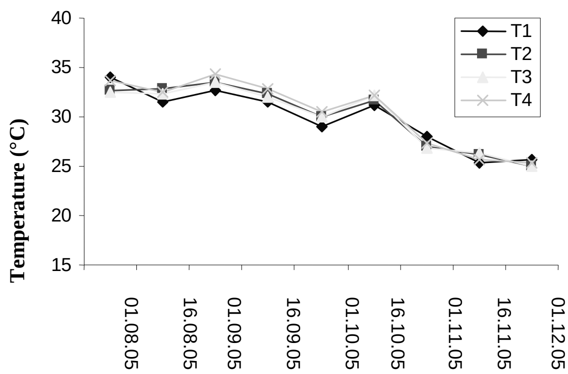

Figure 1. Fortnightly variations of water temperature (°C) in different treatments.

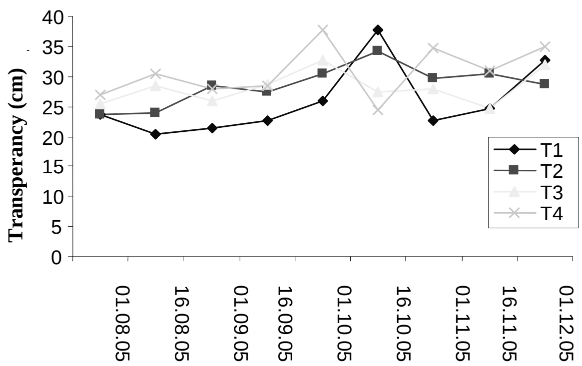

Figure 2. Fortnightly variations of water transparency (cm) in different treatments.

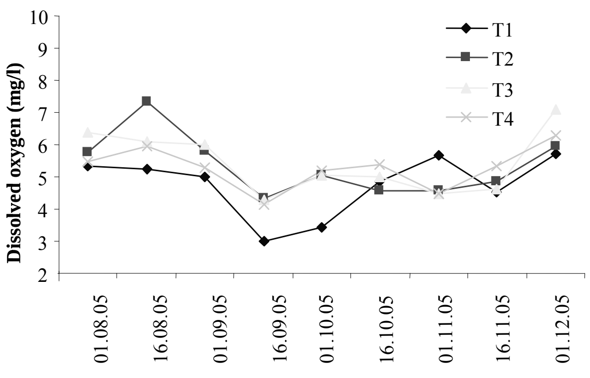

Figure 3. Fortnightly variations of Dissolved oxygen (mg/L) in different treatments.

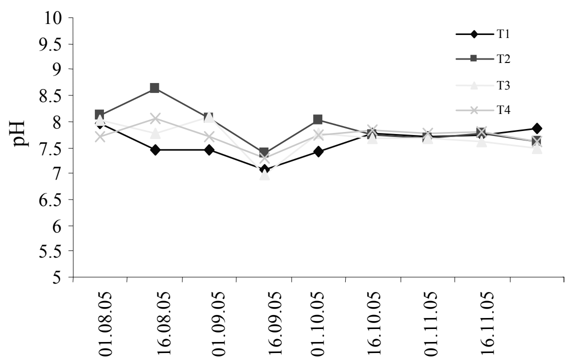

Figure 4. Fortnightly variations of pH in different treatments.

The mean range of value of chlorophyll-a recorded was varied from 5.14-286.79 µg/L in rice plots. The concentrations of chlorophyll-a were significantly higher in T_3 (Figure 5). The highest (286.79 µg/L) and the lowest (5.14 µg/L) chlorophyll-a concentrations were found in T_3 and in T_4, on respectively.

Alkalinity (mg/L): In the study period, the average alkalinity recorded varied from 30.0-100.0 mg/L in rice plots. The highest value (100.0 mg/L) of alkalinity was recorded in the treatment of T_2 on 16th November and lowest value (30.0 mg/L) of the same was in T_1 on 1st October. The values of alkalinity showed remarkable fortnightly variations among the four treatments in the experiment (Figure 6).

Ammonia (mg/L): During the experimental period, the average ammonia recorded varied from 0.03-1.09 mg/L in rice plots. The values of ammonia showed remarkable fortnightly variations among the four treatments in the experiment (Figure 7).

Phosphate-phosphorus (mg/L): In the study period, the average phosphate-phosphorus (PO_4-P) recorded varied from 0.04-0.87 mg/L in rice plots. The highest value (0.87 mg/L) of PO_4-P was observed in T_3 on 1st August and the lowest (0.04 mg/L) of the same was recorded in T_2 on 1st August (Figure 8).

Nitrate-nitrogen (mg/L): During the study period, the average nitrate-nitrogen recorded varied from 0.05-0.22 mg/L in rice plots. The values of nitrate-nitrogen showed remarkable fortnightly variations among the four treatments in the experiment (Figure 9).

Nitrite-nitrogen (mg/L): In the study period the average nitrite-nitrogen (NO_2-N) recorded varied from 0.007-0.062 mg/L in rice plots. The highest (0.062 mg/L) value of NO_3-N was recorded in the treatment T_1 on 1st September and lowest (0.005 mg/L) value of the same was found in T_1 on 16th September (Figure 10).

Growth, Survival and Production of Prawn and Mola

The mean stocking weight, the mean harvesting weight, the survival rate, the specific growth rate (SGR) and the mean production of prawn and mola of different treatments are shown in Table 2. The culture periods of prawn in the treatments were 279 days, 456 days, 384 days and 384 days, respectively.

Yield of Rice and Straw

The yields of rice recorded were 3.71 mt/ha, 2.88 mt/ha, 3.33 mt/ha and 3.04 mt/ha in T_1, T_2, T_3 and T_4, respectively. The highest yield of rice obtained 3.71 mt/ha in T_1 and the lowest of the same was recorded 2.88 mt/ha in T_2 (Table 3).

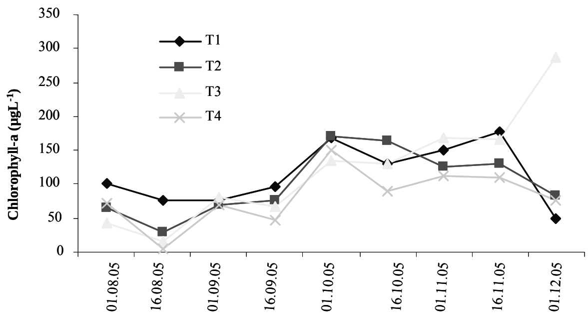

Figure 5. Fortnightly variation of chlorophyll-a (µg/L) in different treatments.

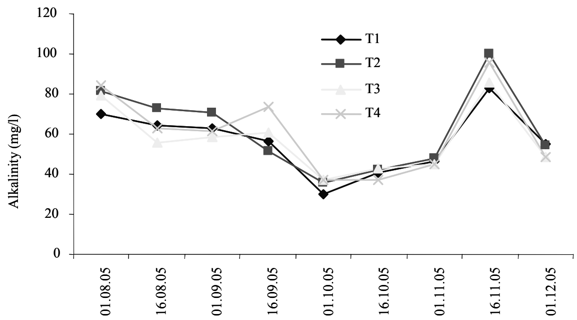

Figure 6. Fortnightly variations of alkalinity (mg/L) in different treatments.

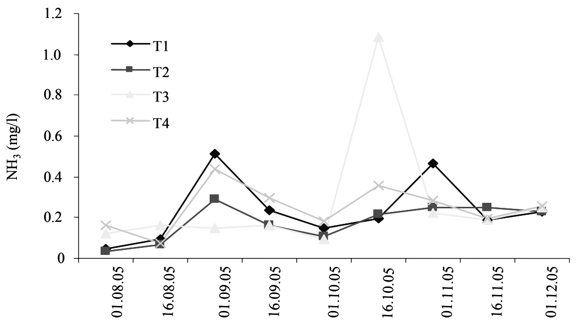

Figure 7. Fortnightly variations of NH_3 (mg/L) in different treatments.

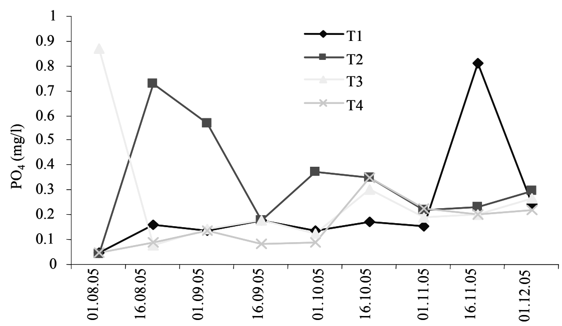

Figure 8. Fortnightly variations of PO_4 (mg/L) in different treatments.

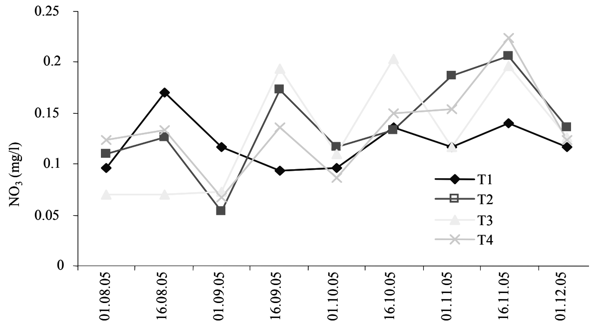

Figure 9. Fortnightly variation of NO_3 (mg/L) in different treatments.

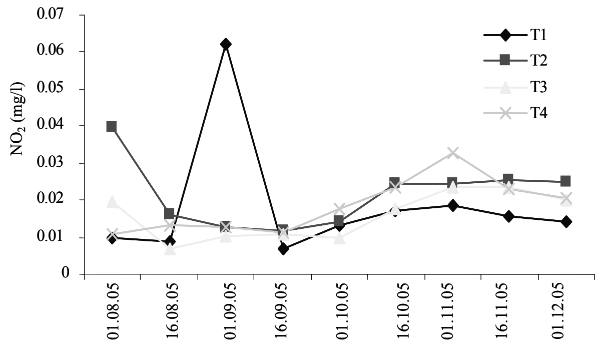

Figure 10. Fortnightly variation of NO_2 (mg/L) in different treatments.

Table 2. Growth, Survival and production of prawn and mola under different treatments

Treatment	Fish species	Mean stocking wt. (g)±SE	Mean wt. (g) of harvesting±SE	Survival (%)	SGR (%)	Production (kg ha^{-1}) 120 $days^{-1}$ Species wise	Total
T_1	Prawn	$1.13±0.02^a$	$52.26±3.18^a$	43.02^{ab}	3.14^a	$221.98±11.82^b$	279.89
	Mola	$1.17±0.78^a$	$3.12±0.10^a$	NM	-	$57.91±10.85^a$	
T_2	Prawn	$1.26±0.03^a$	$55.24±4.23^a$	48.08^a	3.10^a	$388.38±11.14^a$	456.16
	Mola	$1.20±0.02^a$	$3.16±0.07^a$	NM	-	$67.78±9.28^a$	
T_3	Prawn	$1.19±0.02^a$	$42.48±2.61^b$	38.07^b	2.93^{ab}	$322.13±39.05^a$	384.29
	Mola	$1.32±0.30^a$	$3.67±0.18^a$	NM	-	$62.16±12.17^a$	
T_4	Prawn	$1.18±0.11^a$	$34.74±0.59^b$	38.97^{ab}	2.78^b	$334.07±9.39^a$	384.74
	Mola	$1.29 ±0.14^a$	$3.57±0.24^a$	NM	-	$50.67±12.62^a$	

NM = Not measured (Mola had bred after stocking, therefore harvesting number was to much high than stocking), Similar alphabets exhibit no significant difference (P< 0.05), Dissimilar alphabets exhibit significant difference (P<0.05).

Table 3. Average yield of rice grain and straw in different treatments

Treatment	Average yield (mt ha^{-1}) Rice	Straw
T_1	$3.71±0.51^a$	$4.31±1.00^a$
T_2	$2.88±0.38^a$	$3.34±0.85^a$
T_3	$3.33±0.44^a$	$3.93±0.80^a$
T_4	$3.04±0.39^a$	$4.18±0.71^a$

Similar alphabets exhibit no significant difference (P< 0.05).

Discussion

Water Quality Parameters

Temperature : Temperature of water is the most important factor in fish production. Water temperature in the rice fields fluctuated between 24.93-34.33°C (Figure 1) under different treatments of the present study. Almost similar ranges of water temperature were reported by Ali (1992), Ghosh (1992), Uddin (1998), Chowdhury (1999), Mondal (2001) and Das (2002) in their studies in rice fields and they obtained ranges as 27-40.1°C, 27-29°C, 21.9-33°C, 27-31.20°C, 26.90-29.60°C and 25.32-32.04°C, respectively. According to them the ranges of water temperature obtained in the present study are within the suitable range for fish culture. However, the water temperature of the experimental plots decreased gradually towards the end of the experiment which was influenced by the gradual decrease in temperature with the advent of winter season.

Water Transparency : The water transparency showed variation with sampling dates and it ranged from 20.33 to 37.67 cm with the mean values of 20.33–37.67 cm, 23.67–34.33 cm, 24.67–32.67 cm and 24.33–37.67 cm in treatments 1, 2, 3 and 4, respectively. The values of transparency showed significant variations (P<0.05) at various sampling dates, which might be due to difference in abundance of phytoplankton. Roy *et al.* (2002) recorded a transparency range from 19 to 55 cm in their Carp-SIS polyculture ponds.

Dissolved Oxygen: Dissolved oxygen (DO) content is probably the only most important water quality parameter in aquaculture. Prolonged exposure to low concentration of DO can be harmful to aquatic life. In the present study, the dissolved oxygen content of water was observed between 3.02-7.31 mg/L. The range of dissolved oxygen contents obtained by Ghosh (1992), Chowdhury (1999), Mondol (2001) and Das (2002) in rice fields and the ranges reported by them were 3.2-4.5 mg/L, 3.8-4.5 mg/L, 3.42-4.26 mg/L and 3.2-4.65 mg/L respectively which lies within the range of present study. The range of dissolved oxygen (3.7-6.0 mg/L) reported by Uddin (1998) was also close to the values obtained in the present study.

Water pH: The pH in the natural water has great importance as it regulates the productivity of water body. In this study the pH values of water in rice fields are found to range from 6.97-8.63, which are almost close to the neutral value indicating suitable condition for fish culture. The ranges of pH values obtained by Ali (1992), Ghosh (1992), Uddin (1998), Chowdhury (1999), Mondal (2001) and Das (2002) were 6.53–7.08, 7.1–8.0, 6.7–7.8, 5.63–8.20, 5.80-6.90 and 6.75-8.30, respectively which they considered them to be within productive level for rice fish culture. Swingle (1967) observed that pH of water ranging from 6.5-9.0 is suitable for fish culture.

Chlorophyll-a: Chlorophyll-a concentration is a good index of phytoplankton population. In the present study, the values of chlorophyll-a were found to range between 5.14 and 286.79 µg/L among the treatments. The range of Chlorophyll-a concentrations recorded by Uddin (1998), Chowdhury (1999), Mondal (2001) and Das (2002) were 14.7-55.1 µg/L, 10.1-41.0 µg/L, 15.99-26.19 µg/L and 24.11-33.31 µg/L, respectively in their study in rice fields which lie within the ranges obtained in the present study. One of the possible causes of higher values of chlorophyll-a was fertilization with urea, variation of water depth and grazing pressure of fish on phytoplankton in the treatments that was practiced in the experimental plots. Ali (1992) recorded the chlorophyll-a concentration of 45.2 µg/L in rice fields in Malaysia.

Total Alkalinity: The values of total alkalinity as recorded during variations sampling dates were found to vary from 30.0-100.0 mg/L with the mean values of 56.52±5.29 mg/L, 61.78±6.93 mg/L, 57.19±5.47 mg/L and 60.59±6.92 mg/L in treatments 1, 2, 3 and 4, respectively with no significant difference. Ophenheimer *et al*. (1978), and Bhowmic and Tripathi (1985) found the total alkalinity range between 64.85-85.36 and 19.4-92.6 mg/L in their research ponds in Bangladesh and India, respectively.

Ammonia Nitrogen (NH_3-N): Ammonia nitrogen was found to range from 0.03-1.09 mg/L with the mean values of 0.24±0.052 mg/L, 0.19±0.029 mg/L, 0.27±0.103 mg/L and 0.25±0.037 mg/L in treatments 1, 2, 3 and 4, respectively. These values were not significantly different among treatments. Wahab *et al.* (1996) recorded NH_3-N of 0.07 to 0.23 mg/L which lie within the range the values of present study. The values of NH_3-N concentration (from 0.05 to 3.85 mg/L) were recorded by Rahman (1999) which are higher than the values of present study.

Phosphate-phosphorus (mg/L): Phosphate-phosphorus is important nutrient for the productivity of a water body. In our study the ranges of phosphate-phosphorus concentrations obtained were 0.04-0.87 mg/L. The range of phosphate-phosphorus values recorded by Ghosh (1992), Mondal (2001) and Das (2002) in rice fields were 0.03-0.99 mg/L, 0.27-0.98 mg/L and 0.51-1.23 mg/L respectively which are almost similar to the values obtained in the present study whereas, Chowdhury (1999) obtained wide range of phosphorus concentrations from 0.14-2.37 mg/L in his study. However, the values of phosphate-phosphorus concentrations obtained in the present study lie within the ranges reported by them. Alikunhi (1957) suggested that good productive pond water for fish cultivation should have a concentration of phosphate within the range of 0.02-0.4 ppm.

Nitrate-nitrogen (mg/L): To maintain good productivity of water body nitrate-nitrogen is very essential. The range of nitrate-nitrogen value recorded by Ali (1992) was 0.22-0.23 mg/L; but in the present study, the range of nitrogen concentration obtained as 0.05-0.22 mg/L which was more or less close to those of the above statements. Azim *et al.* (1995) stated that near about 0.5 mg/L nitrate-nitrogen was suitable for fish culture. Alikunhi (1957) revealed that good productive water for fish cultivation should have a concentration of 0.06 ppm of nitrate. According to their statements, the values of the nitrate-nitrogen recorded in the present study are suitable for fish culture.

Growth, Survival and Production Performance of Prawn and Mola

The average final weights attained by prawn were 52.26 g, 55.24 g, 42.48 g and 34.74 g in treatments T_1, T_2, T_3 and T_4, respectively. The growth rate attained by mola was 3.12 g, 3.16 g, 3.67 g and 3.57 g in treatments T_1, T_2, T_3 and T_4, respectively. In the present study, the highest mean weight gain of prawn was 53.98 g in treatment T_2 and the lowest was 33.56 g in treatment T_4. The differences in weight gain under four treatments were highly significant ($P \leq 0.05$). Haroon and Alam (1992) recorded weight gain of 51.60 g which is more or less similar to the value of present study. The highest mean weight gained by mola was 2.35 g in treatment T_3 and the lowest was 1.95 g in treatment T_1. Mondal (2001) reported that the average growth rate of *A. mola* was 2.7 g which is more or less close to the present study.

The survival rate of prawn recorded in the present study was 43.02%, 48.08%, 38.07% and 38.97% T_1, T_2, T_3 and T_4, respectively. Haroon *et al.* (1989) recorded the survival of prawn as 70.74-82.41% which is higher than the survival rate obtained in the present study; whereas, Haroon and Alam (1992) recorded the survival rate ranged from 53.90-70.24% which is also higher than the survival rate recorded in the present study. The highest survival rate of prawn was observed in T_2 where the stocking density of prawn and mola was 15000/ha and 20000/ha. The survival rate of mola was not being recorded because it had spawned after stocking; therefore harvesting number was too much higher than stocking.

Production of Rice Grain and Straw

In this study, the yield of grain and straw were found to differ significantly ($P<0.05$) among the treatments. The highest yield of grain 3.71 mt/ha and straw 4.31 mt/ha were obtained in T_1 and the lowest production of grain 2.88 mt/ha and straw 3.34 mt/ha were recorded in T_2. Normally, the introduction of prawn-fish in rice fields improves the yield of grain and straw. These increments of grain and straw yield might be associated with the presence of fish in rice fields, which reduces the incidence of weeds and harmful pests by eating upon them. Coche (1967) and Mazid *et al.* (1993) also stated that introduction of fish in the rice fields reduces the infestation of insects and weeds by feeding upon them and thereby improves the yield of rice. These findings agree with the findings of Purba (1998a), Chowdhury (1999), Mondal (2001) and Das (2002) who also obtained significant difference in the yield of grain and straw between the treatments with and without fish in rice fish culture. The yield of rice grain and straw obtained in the present study is more or less similar to the yield of the same recorded by Das (2002). But the yield of rice grain and straw recorded by Chowdhury (1999), Mondal (2001) was less than the yield of the same obtained in the present study. However, the yield of grain recorded by Haroon and Alam (1992), Gupta and Mazid (1993) and Kohinoor *et al.* (1993) in their experiments on rice fish culture was more or less close to the same of this experiment.

According to the findings of present study, it may be concluded that the introduction of prawn and mola in rice fields has profound impacts on the availability of nutrients in the water and soil which ultimately increases the yield of rice grain and straw and at the same time provides an additional yield of prawn and mola from the same land and thus socio-economic condition and nutritional status of poor farmers could be improved by introducing integrated rice-prawn-mola culture system in the farmers rice fields.

Acknowledgement

The authors wish to express their appreciation to Prof.Dr. Mostafa Ali Reza Hossain, Department of Fisheries Biology and Genetics, Bangladesh Agricultural University Mymensingh, for his constant and untiring help; Prof. Md. Mohsin Ali and Prof. Dr. Rahmatullah, Department of Aquaculture, Bangladesh Agricultural University Mymensingh, for their generous cooperation during the research work. Special thanks to Dr. Abdul Wahab, professor, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh, Bangladesh for his cooperation and cordial help in laboratory analyses. We are also grateful to respective rice plot owners for their assistance of conducting the experiment.

References

Ahmed, K. 1981. Nutritional blindness in Bangladesh. In Touch: VHSS News letter, 45: 1-2

Ahmed, K. and Hassan, N. 1983. Nutrition survey of rural Bangladesh 1981-1982. Institute of Nutrition and Food Science, University of Dhaka, Bangladesh.

Akand, A.M. and Hasan, M.R. 1992. Status of Freshwater Prawn (*Macrobrachium* spp.) culture in Bangladesh. In: E.G. Silas (Ed.), Freshwater Prawns, Kerala Agricultural university, Thrissur. India: 32-41.

Ali, A.B. 1992. Some ecological aspect of fish population in tropical rice fields. Hydrobiol., 190: 215-222.

Alikunhi, K.H. 1957. Fish culture in India. Farm Bull. India Counc. Agric. Res., 20: 1-144.

Arce, R.G. and dela Cruz, C.R. 1979. Yield trials on rice fish culture at the Fresh Water Aquaculture Centre. Fish. Res. J. Philipp., 4(1): 1-8.

Azim, M.E., Talukder, G.S., Wahab, M.A., Haque, M.M. and Haque, M.S. 1995. Effect of liming and maintenance of total hardness levels on fish production in fertilized ponds. Progress. Agric., 6(2): 7-14.

BBS (Bangladesh Bureau of Statistics). 1998. Statistical Division, Ministry of Planning, Government of the People's Republic of Bangladesh, 370 pp.

Bhowmic, M.I. and Tripathi, S.D. 1985. The plankton and fish growths of ponds under semi-intensive fish culture in acid soils of Jalpaiguri, West Bengal. India, J. Inland Fish. Soc., 17(1-2): 39-47.

BRRI. 1999. "Adunik Dhaner Chash" (in Bengali). Bangladesh Rice Res. Int. Jaydebpur, Gazipur, 53 pp.

Chowdhury, M.T.H. 1999. Studies on the suitability of culture of *Amblypharyngodon mola* in rice fields alone and in combination with *Puntius gonionotus* and *Cyprinus carpio*. MSc. thesis, Mymensingh: Bangladesh Agricultural University.

Coche, A.G. 1967. Fish culture in rice fields, a world wide synthesis. Hydrobiol., 30: 1-44.

Das, B.C. 2002. Studies on the effects of stocking density on growth, survival and yield of *Amblypharyngodon mola* and the performance of *Rohtee cotio* in combination with *Barbodes gonionotus* and with *Cyprinus carpio* in rice fields. MSc. Thesis. Mymensingh: Bangladesh Agricultural University.

dela Cruz, C.R., Sevilleja, R.C. and Torres, J. 1992. Rice-fish systems Guimba, Nuvea Ecija, Philippines. In

Farmers Proven Integrated Agriculture-Aquaculture: A Technology Information kit. ICLARM and International Institute of Rural Reconstruction (IIRR), Philippines: 1-4.

FAO (Food and Agriculture Organization). 1977. China: Recycling of Organic Wastes in Agriculture. FAO soils. bull., Rome, 40 pp.

Ghosh, A. 1992. Rice- Fish farming development in India: Past present and future. Rice Fish Research and Development in Asia. In: C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (Eds.), International Cent. for Living Aquatic-Resource Management, Manila, 24: 27-43.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research. 2nd edition, John Wiley and Sons, 697 pp.

Gupta, M.V. and Mazid, M.A. 1993. Feasibility and potentials for integrated rice-fish systems in Bangladesh. Paper presented at twelfth session of the FAO Regional farm Management Commission for Asia and the Far East. 11-14 December, Dhaka, Bangladesh: 1-19.

Halwart, M. 1994. Fish in rice fields. In: P. Millan and J. Margraf (Eds.), Philippines freshwater ecosystem. Tropical ecology program, Visayan State College of Agriculture, Baybay, Leyte, Philippines.

Haroon, A.K.Y. and Alam, M. 1992. Effect of supplemental feed on *Macrobrachium rosenbergii* and trials with Silver barb and Tilapia. Bangladesh Jour. Fish., 15(2): 115-122.

Haroon, A.K.Y., Alam, M. and Mazid, M.A. 1989. An experimental study on integrated paddy-cum-fish/shrimp farming practice in Bangladesh. Effect of stocking densities on growth and yoeld. Bangladesh Jour. Fish., 12(1): 101-108.

Hora, S.L. and Pillay, T.V.R. 1962. Handbook on fish culture in the Indo-pacific region. FAO Fish, Biol. Tech. Pap., 14: 1-204.

Hossain, M.I. 1995. Studies on the growth, production and fishery of six major and exotic carps in a selected baor. An M.S. Thesis. Deptt. of Fisheries Biology and Limnology, Bangladesh Agricultural University, Mymensingh, 115 pp.

Hossain, S.M.A., Salam, M.U. and Islam, M.S. 1990. Effect of alternative row spacing on rice yield in relation to rice-fish culture. Int. J. Tropical Agri., 6: 1-5.

Kamp, K. and Gregory, R. 1993. Fish cultivation as a means to increase profitability from rice fields: Implication for integrated pest management. Paper presented at the Third Asian Regional Integrated Rice-fish Farming Research and Development Workshop, 1-8 June, West Java, Indonesia: 6-111.

Karim, M. 1978. Status and Potential of Bangladesh Fisheries. Ministry of Fisheries and Livestock. Govt. of Bangladesh, Dhaka, 125 pp.

Khoo, K.H. and Tan, E.S.P. 1980. Review of Rice-Fish Culture in Southeast Asia. In: R.S.V. Pullin and Z.H. Shehadeh (Eds.), Integrated Agriculture Aquaculture Farming Systems. ICLARM Conf. Proc., 4: 1-14.

Kohinoor, A.H.M., Shaha, S.B., Akhteruzzaman, M. and Gupta, M.V. 1993. Suitability of short cycle species *Puntius gonionotus* (Bleeker) for culture in rice fields. In: C.R. dela Cruz (Ed.), Role of Fish in Enhancing Rice Fields Ecology in Integrated Pest Management. ICLARM Conf. Proc., 43-50.

Li, K. 1988. Rice-Fish culture in China: a Review. Aquaculture, 71: 173-186.

Lightfoot, C., Roger, P., Cagauan, A. and dela Cruz. C.R. 1990. A fish crop may improve rice yields and rice fields. NAGA, The ICLARM Quaterly, 13(4): 12-13.

Mazid, M.A., Bakshi, B.C., Das, A.K. and Bari, N. 1993. Fish culture in rice field. FSRDP and BARC, 1-27.

Mondal, S. 2001. Studies on the cultural suitability of *Rohtee cotio* in combination with *Amblypharyngodon mola* and *Cyprinus carpio* in rice fields. MSc. thesis. Deptt. Of Fisheries management, Mymensingh: Bangladesh Agricultural University.

Ophenheimer, J.R., Ahmed, M.G., Huq, A., Haque, K.A., Alam, A.K.M.A., Aziz, K.M., Ali, S. and Haque, A.S.M.N. 1978. Limnological studies of three ponds in Dhaka, Bangladesh. Bangladesh J. Fish., 1(1): 10-28.

Purba, S. 1998. The impact of rice-fish culture on rice-yield, fertilizer and pesticide use. Indonesian J. of Crop Science, 13(2): 41-50.

Rahman, M.M. 1999. Effects of species combination on pond ecology and growth of fish in Carp-SIS polyculture system. MSc. thesis, Department of Fisheries Management, Mymensingh: Bangladesh Agricultural University.

Roy, N.C., Kohinoor, A.H.M., Wahab, M.A. and Thilsted, S.H. 2002. Evaluation of performance of Carp-SIS polyculture technology in the rural farmers' pond. Asian Fisheries Science., 15: 41-50.

Singh, V.P., Early, A.C. and Wickham, T.H. 1980. Rice agronomy in relation to rice-fish culture. Brackish water Aquaculture Centre, University of Philippines, Leganes, Philippines, 15-34.

Swingle, H.S. 1967. Standardization of chemical analyses for waters and pond muds. FAO Fish. Rep., 4(44): 397-421.

Thilsted, S.H., Ross, N. and Hassan, N. 1997. The role of indigenous fish species in food and nutrition security in Bangladesh. NACA News letter, July-Dec, 13 pp.

Uddin, M.J. 1998. Effects of fish culture in rice fields on the yields of rice and nutrients availability in soil, straw and grain. MSc. Thesis, Department of Fisheries Management, Mymensingh: Bangladesh Agricultural University.

Wahab, M.A., Aziz, M.E., Haque, M.M. and Ahmed, Z.F. 1996. Effects of frequency of fertilization on water quality and fish yields. Progress. Agric., 7(2): 33-39.

Weibel, H. 1992. Comparative economics of pesticide use in rice and rice-fish farming, In: C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce. V.R. Carangal and M.P. Bimbao (Eds.), Rice-fish Research and Development in Asia. ICLARM conf. Proc., 24: 245-254.

Williams, D. and Khan, N.A. 2003. Freshwater prawn farming in gher system: indigenous technology developed in south-west Bangladesh. GOLDA project, CARE Bangladesh, 45 pp.

Zar, Z.H. 1974. Biostatistical Analysis. Printice Hall Inc. Englewood Clifs, N.J., 592 pp.

Zhang, J. 1986. The effect of drought on rice-fish culture and its countermeasures in Chogqing. In: selected papers on rice-fish culture. National Aquatic Products Bureau, Beijing.