Bangladesh J. Fish. Res., 12(1), 2008: 41-52

Performance of *Amblypharyngodon mola* with *Barbodes gonionotus, Cyprinus carpio* and *Macrobrachium rosenbergii* in rice-fish culture system

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Abstract
An experiment was conducted to assess the performance of mola (*Amblypharyngodon mola*) in rice fish culture system with freshwater prawn *Macrobrachium rosenbergii*), Thai silver barb (*Barbodes gonionotus*) and common carp (*Cyprinus carpio*) for a period of 4 months at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh. Four treatments viz., treatment-I (T_1) with *A. mola* and *M. rosenbergii*; treatment-II (T_2) with *A. mola*, *M. rosenbergii* and *B. gonionotus* ; treatment-III (T_3) with *A. mola*, *M. rosenbergii* and *C. carpio*, and treatment- IV (T_4) as control (without fish) were used in triplicate. All treatments were equally fertilized with urea (200 kg/ha), TSP (150 kg/ha) and MP (75 kg/ha). The mean values of water quality parameters viz., temperature, dissolved oxygen, pH, nitrate-nitrogen showed a very small variations among different treatments, but phosphate-phosphorus and chlorophyll-a were relatively higher in T_4 without fish (i.e., control). The fish production of 480.5 kg/ha in T_3 was significantly higher than that of 355.6 kg/ha T_2 and 223.8 kg/ha in T_1. The values of soil organic matter, total-nitrogen, phosphorus and potassium at harvest were significantly ($P<0.05$) higher in the treatments with fish than without fish, but pH did not show any significant differences. The yield of rice grain and straw was also obtained significantly ($P<0.05$) higher in the treatments with fish. The increase in grain was higher over the control by 11.81%, 9.41% and 14.76% and that in straw was by 9.83%, 4.77% and 13.29% in T_1, T_2, and T_3 respectively.

Key wards: Rice-fish culture, *Amblypharyngodon mola*, *Macrobrachium rosenbergii*, *Barbodes gonionotus, Cyprinus carpio*

Introduction

Bangladesh is a fishery resourceful country. The country offers a large potential for the development of inland fishery and aquaculture. Fisheries sector plays an important role in the economy of Bangladesh in terms of nutrition, income, employment generation and foreign exchange earning. This sector contributes about 4.07% of total GDP, 22% of agricultural production, 4.90% of export earning and about 63% of animal protein to

our daily diet (DoF 2008). The country has a vast potential of integrating fish and prawn culture with rice farming. Integrated rich-fish farming probably the best example of integration where rice and fish are directly benefited by each other. Activities of fishes 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 (Khoo and Tan 1980, Zhang 1986, Li 1988, Cruz *et al.* 1992, Kamp and Gragory 1993). Lightfoot (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. Bangladesh has more than 2.83 million ha of seasonal paddy fields where water remains 4-6 months (DoF 2008). The carrying capacities of these lands are not utilized to the fullest extent, but there exists tremendous scope for increasing fish/prawn production integrating with rice. This practice will help to optimize land use without degradation, a suitable ecosystem.

More than 50 small indigenous species of fishes (SIS) play an important role in the national diet of Bangladesh which may be brought under culture and management. The small indigenous species of fishes (SIS) of Bangladesh are generally considered to be those fishes which grow to a length of about 25 cm or 9 inches (Felts *et al.* 1996, Hossain and Afroze 1990). In the past, these small indigenous fish species were abundantly available in rivers, beels, jheels, canals, haors, baors, ditches and flood plains of Bangladesh (Jhingran and Talwar 1991, Shafi and Quddus 1982, Ahmed 1984) and had a low market value. But now a days, these species have gradually been disappearing from the systems which in turn severely affecting the biodiversity of our ecosystem. Malnutrition and protein deficiency of the rural people can be eliminated and their economic conditions can be improved through cultivation of small indigenous fish species (SIS) separately or in combination with carps in rice fields. It is expected that the result of the present study be of greatly benefit the rice-fish farming communities and will be of great use for scientists to undertake fruitful research programme in future.

Materials and methods

Site selection and land preparation

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. The facility consists of 12 experimental plots, each comprising an area of 160m^2 and rectangular in shape. Small water channels (0.70m width and 0.30m depth) were made between the plots to supply water to them. Embankments (0.70m height and 0.50m width) were made surrounding the experimental areas. A common inlet and outlet was provided on the dykes of each plot to regulate water depth of 0.3-0.4m. A small ditch was constructed in the middle position in each plot covering an area of 1.5 m^2 with 0.50 m depth. The width and depth of the trenches were 40cm and 30 cm, respectively, which were almost similar to the practice of the farmers in Indonesia (dela Cruz 1992) and in Bangladesh (Mazid *et. al.* 1992). Wetland preparation was followed in the experiment, which is practiced in most

tropical countries (Singh *et. al.* 1980). All the experimental plots were fertilized with triple super phosphate (TSP) and murate of potash (MP) at the rate of 150 kg/ha and 75 kg/ha respectively recommended by BRRI (1999).

Experimental design

The experiment was laid out in a randomized block design (RBD) with four treatments *viz.*, Treatment-I (T_1), Treatment-II (T_2), Treatment-III (T_3) and Treatment-IV (T_4) and randomly assigned in each with three replications Viz., R_1, R_2 and R_3. *A. mola* was stocked with *M. rosenbergii* in T_1, with *M. rosenbergii* and *B. gonionotus* in T_2 and with *M. rosenbergii* and *C. carpio* in T_3. Treatment IV (T_4) was kept as control i.e., without fish. The stocking densities given were 16000/ha for *A. mola* and 9000/ha for *M. rosenbergii* in T_1; 10,800/ha for *A. mola*, 7,600/ha for *M. rosenbergii* and 2,700/ha for *B. gonionotus* in T_2 and 10,800/ha for *A. mola*, 7,600/ha for *M. rosenbergii* and 2,700/ha for *C. carpio* in T_3.

Rice transplantation and management

In rice-fish culture system, high yielding varieties (HYV) that 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 and dela Cruz. *et al.,* 1992). For this purpose seedlings of BR-10 were transplanted in the experimental plots on the 2nd August 2003. 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. Water level was kept as low as 2-4 cm up to 12 days after transplanting to allow the rice seedlings well established and to initiate tillers growth. The urea was top dressed in three equal doses at 16, 45 and 65 days of rice seedling transplantation. No pesticide was applied to the crop during the experimental period.

Stocking of fingerlings and their management

The fish fingerlings were stocked 27 days after transplanting of rice seedlings and prawn juveniles were stocked 30 days after transplanting of rice seedlings in the experimental plots. Low-cost supplementary feed comprising of rice bran and oil cake at 1:1 ratio were supplied once daily at the rate of 3% of body weight of fish. Water depth were maintained 0.3 to 0.4m throughout the study period. Observation of fish health were done in each sampling date.

Study of water quality parameters

During the study period, the values of water temperature, dissolved oxygen, pH, chlorophyll-a, nitrate-nitrogen and phosphate-phosphorus were recorded fortnightly. Water temperature and dissolved oxygen were measured directly in the field with the help of a Celsius thermometer and a digital electronic DO meter (YSI, MODEL 58). Water pH was measured with the help of an electrical pH meter (JENWAY, MODEL 3020).The concentration of nitrate-nitrogen (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 pillow nitrover-3 and phosver-3. 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 wavelengths.

Harvesting of rice and fish

The rice was harvested on the 30th November 2003 after 120 days of transplantion. The grains and straw were then cleaned and sun dried for three days. Then the weights of dried grain and straw were recorded separately (mt/ha). The fishes and prawns were harvested immediately after harvesting of rice. The collected fishes/prawns from the plots were counted and the number was recorded separately species wise and plot wise to determine the growth. The length and weight of fish were recorded separately with the help of measuring scale and a portable electronic balance (Model OHAUS CT1200-S). The gross and net yield of fish for each treatment was determined.

Collection and preparation of soil samples

Soil samples were collected from each unit plot at a depth 0-15 cm from the surface in two installments, first before application of fertilizer and finally after harvest of fish. After removing weeds, plant roots, stubble's etc., the samples were air dried and ground to pass through a 2 mm mesh size sieve. Then these cleaned ground soil samples were stored in clean plastic container separately treatment wise for subsequent physical and chemical analysis using standard methods of Pipers (1950), Jackson (1962), Black (1965) and Page *et al.* (1989).

Data analysis

All the data collected during the experiment were recorded and preserved in computer. The data obtained in the experiment were analyzed statistically using analysis of variance (ANOVA). The mean values were compared to Duncan's Multiple Range Test (Gomez and Gomez 1984). SPSS 11.5 statistical package was used for analysis of all data.

Results and discussion

Water quality parameters in rice fields

The values of water quality parameters of the present study *viz.*, water temperature, dissolved oxygen (DO), pH, nitrate-nitrogen, phosphate-phosphorus and chlorophyll-a have been shown in Table 1. Water temperature in the rice fields fluctuated between 26.75-29.56 °C under different treatments of the present study. Almost similar ranges of water temperature were reported by Ali (1992), Ghosh (1992), Uddin (1998),

Chowdhury (1999), Mondol (2001) and Das (2002) in their studies in rice fields were 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.

Table 1. Mean values (±SE) of water temperature, dissolved oxygen, pH, NO_3-N, PO_4-P and Chlorophyll-a under four different treatments. Dissimilar alphabets exhibit significant differences ($P < 0.05$)

Treatment	Parameters					
	Temperature (°C)	DO (mg/l)	pH	NO_3-N (mg/l)	PO_4-P (mg/l)	Chlorophyll-a (μg/l)
T_1	28.33±0.44 (26.75-29.50)	4.10±0.03 (3.91-4.44)	7.21±0.08 (6.84-7.50)	1.89±0.06 (1.65-2.20)	0.60±0.01 (0.48-0.72)	18.34±0.5^b (15.55-21.10)
T_2	28.34±0.44 (26.83-29.52)	4.15±0.03 (3.96-4.30)	7.17±0.07 (6.80-7.43)	1.81±0.06 (1.51-2.10)	0.56±0.03 (0.32-0.73)	18.22±0.4^b (15.98-20.43)
T_3	28.33±0.45 (26.74-29.56)	4.07±0.02 (3.88-4.27)	7.20±0.08 (6.83-7.54)	1.86±0.05 (1.61-2.05)	0.56±0.03 (0.41-0.71)	18.34±0.3^b (16.60-20.02)
T_4	28.32±0.43 (26.85-29.52)	4.11±0.03 (3.95-4.40)	7.16±0.08 (6.78-7.42)	1.84±0.05 (1.67-2.00)	0.77±0.03 (0.64-1.00)	25.47±1.9^a (20.60-30.12)

In the present study, the dissolved oxygen contents of water were found to range between 3.88-4.44 mg/l which are almost similar to the range of dissolved oxygen contents obtained by Ghosh (1992), Chowdhury (1999), Mondol (2001) and Das (2002) in rice fields 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. The pH values of water in the present study found to range between 6.78-7.54, which are almost close to the neutral value indicating suitable condition for fish culture. This range of pH values are more or less similar to the ranges of pH values obtained by Ali (1990), Ghosh (1992), Uddin (1998), Chowdhury (1999), Mondol (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. The range of nitrate-nitrogen values recorded by Ali (1992) and Whitton *et al.* (1988) were 0.22-0.23 mg/l and 0.006-0.05 mg/l respectively. But the range of it (1.51-2.20 mg/l) obtained in the present study was higher than those of the above statements. One of the possible causes of higher values of nitrate-nitrogen might be due to fertilization with urea that was practiced in the experimental plots. However, the ranges of nitrate-nitrogen values recorded by Ghosh (1992), Chowdhury (1999), Mondol (2001) and Das (2002) ranged from 0.02-2.60 mg/l, 1.43-3.16 mg/l, 1.60-2.83 mg/l and 1.60-3.22 mg/l respectively were more or less close to the values obtained in the present study. The ranges of phosphate-phosphorus concentrations obtained in the present study was 0.32 to 1.00 mg/l which is almost similar to the values recorded by Ghosh (1992), Mondol (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. The range of chlorophyll-a values (15.55-30.12 μg/l) obtained in the present study was found to lie within the ranges 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. Among all the treatments significantly higher concentration of Chlorophyll-a was recorded in T_4 (without fish)

than T_1, T_2 and T_3 (with fish), which might be attributed to grazing pressure of fish on phytoplankton. Except chlorophyll-a other water quality parameters did not show any significant differences among the treatments.

Growth of fish and prawn

The growth rate of *A. mola* by average, net and percentage of increase did not show any significant differences among the treatments (Table 2). However, the average growth rate of *A. mola* by length and weight recorded in T_1, T_2 and T_3 were 6.59cm and 2.58g, 6.61cm and 2.56g and 6.71cm and 2.58g, respectively which are higher than the growth rates 5.30cm and 1.55g and 6.20cm and 1.90gm obtained by Chowdhury (1999) and Das (2002), respectively. Mondal (2001) reported that the average growth rate of *A. mola* was 6.7cm and 2.7gm which is similar to the present study. The growth rate attained by *M. rosenbergii* 15.17cm and 38.47g in T_1, 15.14cm and 38.40g in T_2 and 15.33cm and 38.77g in T_3 by average increase and 7.52cm and 34.30g in T_1, 7.58cm and 34.26g in T_2 and 7.7cm and 34.54g in T_3 by net increase in length and weight, respectively. Whereas, by percentage of increase it was found to attain 98.30%, 100.26% and 100.92% in length and 822.54%, 811.85% and 816.55% in weight in T_1, T_2 and T_3, respectively. There was no significant differences in growth rate of *M. rosenbergii* among the treatments. The growth recorded for *B. gonionotus* were 17.91cm and 81.61g in T_2 by average increase in length and weight respectively, and by net increase they were 11.11cm and 75.27g and the percentage of increase were 163.38% and 1187.22% in length and weight respectively. The growth rate of *B. gonionotus* by average, net and percentage of increase in length and weight recorded by Chowdhury (1999) were 17.03cm and 71.66g, 11.33cm and 66.3g and 197.85% and 1246.35% respectively which are more or less close to the findings of the present study. But the growth rate 17.30cm and 75.5g, 10.60cm and 69.40g and 158.21% and 1137.70% respectively reported by Das (2002) were less than the growth rate obtained in the present study. The growth rate of this fish 38.0g and 54.42g respectively reported by Akhteruzzaman *et al.* (1993) and Uddin *et al.* (2001) were also less than the growth rate obtained in the present study. But the growth rate of this fish (95-115g) recorded by Hossain *et al.* (1988) was higher than the growth rate of the present study. The growth rate observed for *C. carpio* was 22cm and 178g by average increase and 13.59cm and 169.59g by net increase in length and weight respectively. The growth rate of this fish recorded by Mondal (2001) was 20.3cm and 184.7g and by Das (2002) were 21.70cm and 170.0g respectively by average increase in length and weight which are more or less close to the growth rate obtained in the present study. But the growth rate (63g and 122.67g) recorded by Akhteruzzaman *et al.* (1993) and Chowdhury (1999) were far less than the growth rate recorded in the present study.

Table 2. Growth rate, survival rate and production of fish under three different treatments. Dissimilar alphabets exhibit significant differences ($P < 0.05$)

Treatment	Species Stocked	Number/ha		Average Weight (g)		Weight gained		Survival rate	Production (Kg/ha)	
		Stocked	Harvested	Initial	Final	Net Increase	(%) increase		Gross	Net
T_1	*A. mola*	16,000	6,240	0.79±0.02	2.58±0.01	1.79±0.01	226.58	39	16.10	11.17
	M. rosenbergii	9,000	5,400	4.17±0.08	38.47±1.5	34.29±1.38	822.54	60	207.7[a]	185.2[a]
Total		25,000	11,640						223.8[c]	196.4[c]
T_2	*A. mola*	10,800	4,104	0.80±0.03	2.56±0.04	1.76±0.02	220.0	38	10.51	7.22
	M. rosenbergii	7,600	4,332	4.22±0.04	38.46±1.4	34.26±1.41	811.85	57	166.6[b]	148.4[b]
	B. gonionotus	2,700	2,187	6.34±0.05	81.61±0.8	75.27±0.76	1187.22	81	178.48	164.62
Total		21,100	10,623						355.7[b]	320.4[b]
T_3	*A. mola*	10,800	4,644	0.77±0.01	2.58±0.03	1.81±0.04	220.0	43	11.98	8.41
	M. rosenbergii	7,600	4,028	4.23±0.07	38.77±0.7	34.54±0.77	816.55	53	156.2[b]	139.1[b]
	C. carpio	2700	1,755	8.41±0.02	178.0±1.9	169.59±1.93	2016.53	65	312.39	297.63
Total		21,100	10,427						480.5[a]	445.[2]

Survival rate of fish and prawn

The survival rate of *A. mola* recorded for T_1, T_2 and T_3 were 39%, 38% and 43%, respectively (Table 2). The survival rates of this fish recorded by Chowdhury (1999), Mondal (2001) and Das (2002) were almost similar to the survival rates of the present study and values obtained by them were 42% and 37%, 35% and 42%, and 44%, 42% and 37%, respectively. Survival of mola did not show any significant differences among the treatments. The survival rates of *M. rosenbergii* recorded in the present study were 60%, 57% and 53% T_1, T_2 and T_3, respectively. Haroon and Alam (1992) recorded the survival of *M. rosenbergii* as 70.74-82.81% which are higher than the survival rate obtained in the present study; whereas, in another experiment the survival rate (53.90-70.24%) recorded by Haroon and Alam (1992) were is more or less similar to the survival rates recorded in the present study. Survival of prawn did not show any significant differences among the treatments. The survival rate recorded for *B. gonionotus* and *C. carpio* were 81% and 65% respectively. Survival rate of *B. gonionotus* recorded by Rahman *et al.* (1995), Akhteruzzaman *et al.* (1993), Chowdhury (1999) and Das (2002) were 65%, 68%, 62% and 69% respectively in their study, was lower than the survival rate recorded in the present study. Survival rate of *C. carpio* (58% and 63%) recorded by Mondal (2001) and 61% by Das (2002) were almost similar to the survival rate of this fish recorded in the present study. Survival rate of this fish 53% and 55% recorded by Akhteruzzaman *et.al.*(1993) and Chowdhury (1999), respectively were slightly lower than the same recorded in the present study, whereas, the survival rate (81.06%) reported by Islam *et al.* (1998) was much higher than the present study.

Production of fish and prawn

Among all the treatments the significantly higher gross (480.54 kg/ha) and net (445.17 kg/ha) production of fish were obtained in T_3 in combination with *A. mola, M. rosenbergii* and *C. carpio* and the lowest (223.84 kg/ha and 196.39 kg/ha) were recorded in T_1 in combination with *A. mola* and *M. rosenbergii.* In another treatment T_2 gross (355.64 kg/ha) and net (320.21 kg/ha) production of fish were obtained in combination with *A. mola, M. rosenbergii* and *B. gonionotus.* The gross and net production of *A. mola* obtained significantly higher in T_1 (16.10 kg/ha and 11.17 kg/ha) than in T_2 (10.51 kg/ha and 7.22 kg/ha) and in T_3 (11.98 kg/ha and 8.41 kg/ha), respectively (Table 2). The production of newly produced fry was not counted here, as they were too small to be harvested. The gross production of *A. mola* (12.6 kg/ha, 8.03 kg/ha and 9.11 kg/ha) recorded by Chowdhury (1999) was more or less close to the production obtained in the present study. Whereas, the gross production of *A. mola* (25.88 kg/ha, 26.88 kg/ha and 29.23 kg/ha) recorded by Das (2002) were higher than the production obtained in the present study. The gross and net production of *M. rosenbergii* were 207.74 kg/ha and 185.22 kg/ha in T_1 was significantly higher than 166.61 kg/ha and 148.41 kg/ha in T_2 and 156.17 kg/ha and 139.13 kg/ha in T_3, respectively. The production of *M. rosenbergii* in rice field recorded by Haroon and Alam (1992) 217-265 kg/ha/230 days was similar to the production obtained in the present study. The gross and net production of *B. gonionotus* recorded in the present study was 178.48 kg/ha and 164.62 kg/ha respectively.

The gross production of this fish recorded by Islam *et al.* (1998), Chowdhury *et al.*(2001) and Uddin *et al.*(2001) were 184.17 kg/ha, 175.21 kg/ha and 142.8 kg/ha respectively which is more or less similar to the production obtained in the present study. The gross and net production of this fish (260.48 kg/ha and 239.43 kg/ha) recorded by Das (2002) was higher than the production obtained in the present study. The gross and net production of C. *carpio* obtained in the present study were 312.39 kg/ha and 297.63 kg/ha, respectively which were found to lie within the range 300-747 kg/ha recorded by Yuchang and Yixian (1988) from the stocking of *C. carpio* in rice fields. Whereas, the yield of this fish recorded by Khan *et al.* (1997) and Chowdhury (1999) were 233.49 kg/ha and 252.94 kg/ha respectively, which are less than the production obtained in the present study. On the other hand, Mondal (2001) and Das (2002) recorded higher production of this species (523.16kg/ha and 518.50kg/ha respectively) than the production of the present study.

Production of rice grain and straw

In the present study, the yield of grain and straw were found to differ significantly ($P<0.05$) between the treatments with fish and without fish. The highest yield of grain 6.22mt/ha and straw 7.84mt/ha were obtained in T_3 where *A. mola*, *C. carpio* and *M. rosenbergii* were stocked together and the lowest production of grain 5.12mt/ha and straw 6.31mt/ha were recorded in T_4 where no fish was stocked (Table 3).

Table 3. Average yield of grain and straw in different treatments. Dissimilar alphabets exhibit significant differences ($P< 0.05$)

Treatments	Average yield (mt/ha)		% of increase over the control	
	Grain	Straw	Grain	Straw
T_1	6.06 ± 0.05^{ab}	7.60 ± 0.18^{ab}	11.81	9.83
T_2	5.90 ± 0.06^{b}	7.25 ± 0.09^{bc}	9.41	4.77
T_3	6.22 ± 0.05^{a}	7.84 ± 0.07^{a}	14.76	13.29
T_4	5.12 ± 0.29^{c}	6.31 ± 0.43^{c}		

The increased yields of both grain and straw in the treatments with fish than without fish (control) indicate that the introduction of fish in rice fields improves the yield of grain and straw. These findings agree with the findings of Purba (1998), Chowdhury (1999), Uddin *et al.*(2000), 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), and Uddin *et al.* (2001) were 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 were more or less close to the same obtained in the present study. The yield of grain and straw were

found to increase in the treatments with fish from that of control (without fish) by about 11.81%, 9.41% and 14.76% in grain and 9.83%, 4.77% and 13.29% in straw in T_1, T_2 and T_3 respectively and infestation of pest did not occur during the study period. These findings are in conformity with the findings of Hora and Pillay (1962), dela Cruz *et al.* (1992), Lightfoot *et al.* (1990), Chowdhury (1999), Uddin *et al.* (2000) and Das (2002). Mazid *et al.* (1993) and Kumah *et al.* (1996) 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.

Availability of nutrients in soil

The initial (before rice transplantation) and final (after the harvest) values of soil pH did not show any significant difference ($P<0.05$) (Table 4). No significant difference was observed in the initial values of organic matter, nitrogen, phosphorus and potassium among the four treatments, but the final values of them showed significant ($P<0.05$) differences between the treatments with fish and without fish. The significantly higher concentrations of nutrients in the soil with fish than without fish in all the treatments clearly indicate that the introduction of fish in the rice fields improved the nutritional status of soil. These findings of the present study are in conformity with the findings of Middendrop (1985), Xu and Gua (1992), Guant *et al.* (1993), Uddin (1998) and Chowdhury (1999). They stated that the introduction of fish in the rice fields stimulates the activities of microorganisms, increases the availability of organic matter by faeces and increases the release of nutrients for better growth of rice. However, the values of soil nutrients obtained in the present study are more or less close to values of the same recorded by Uddin (1998), Ashrafuzzaman (1999), Mondol (2001) and Das (2002).

Table 4. Concentration of nutrients in soil before rice transplantation and at harvest. Dissimilar alphabets exhibit significant differences ($P< 0.05$).

Treatment	pH		Organic matter (%)		Total N (%)		P (ppm)		K (ppm)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
T_1	6.60 ±0.04	6.65^{a} ±0.02	1.318 ±0.08	2.588^{ab} ±0.04	0.060 ±0.01	0.170^{a} ±0.01	11.077 ±0.65	13.218^{a} ±0.17	58.55^{a} ±0.78	79.431^{a} ±0.88
T_2	6.58 ±0.01	6.54^{b} ±0.02	1.252 ±0.13	2.642^{a} ±0.06	0.075 ±0.01	0.166^{a} ±0.01	11.138 ±0.24	13.576^{a} ±0.39	56.662^{ab} ±0.99	77.265^{a} ±1.38
T_3	6.63 ±0.06	6.60^{ab} ±0.03	1.328 ±0.01	2.257^{b} ±0.16	0.064 ±0.01	0.156^{a} ±0.02	10.585 ±0.18	12.594^{a} ±0.76	54.465^{b} ±0.63	74.642^{a} ±2.65
T_4	6.53 ±0.05	6.56^{ab} ±0.02	1.292 ±0.07	1.904^{c} ±0.03	0.068 ±0.01	0.114^{b} ±0.01	10.714 ±0.33	11.074^{b} ±0.23	55.286^{b} ±0.75	62.466^{b} ±2.14

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(Manuscript received 13 April 2008)