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Effects of fish and prawn culture on physico-chemical parameters of water and rice yield in rice fields

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Abstract
An experiment was conducted with five treatments i.e rice combined with fish having regular urea fertilization (T_1), rice combined with prawn having regular urea fertilization (T_2), rice combined with fish with supplementary feeding (T_3), rice combined with prawn with supplementary feeding (T_4) and without fish and prawn (T_5) was kept as control. The dissolved oxygen values obtained in treatments with fish both in morning and afternoon were lower than the values of prawn containing treatments and control. The values of nitrate-N, ammonia-N, phosphate-P and chlorophyll-a were higher in fish containing treatments than the prawn containing treatments and control. Between the two fish containing treatments the higher gross (539.44 kg/ha) and net (440.14 kg/ha) yield were obtained in T_3 with supplementary feeding and the lower gross (424.88 kg/ha) and net (314.32 kg/ha) yield were recorded in T_1 without supplementary feeding. Again, between two prawn containing treatments the higher gross (108.69 kg/ha) and net (81.92 kg/ha) yield were obtained in T_4 with supplementary feeding and lower gross (64.32 kg/ha) and net (30.98 kg/ha) yield were recorded in T_2 without supplementary feeding. The highest yield of rice grain (3.45 mt/ha) and straw (6.37 mt/ha) were obtained in T_1 with fish having urea fertilization without feeding.

Key words: Rice-fish culture, Rice-prawn culture, Water quality parameters

Introduction

Rice and fish are the staple food for the people of Bangladesh. Fish is the main source of animal protein, providing 17.23 kg/year of the average per capita total intake of protein and 58% of the total animal protein intake in Bangladesh (DoF 2009). Crop land has already been declined in this country by 3.1% from mid 1980 to mid 1990 as reported by Alauddin (2004). In recent years, rice production has become less profitable for farmers due to stagnant yields and high input costs. Hence, there is a move towards diversification out of rice monoculture. One of these is the age-old practice of integrating fish culture with rice farming.

The practice of integrated farming of prawn with rice, fish, and vegetables is spreading, particularly among small-scale farmers, providing a year-round supply of crops for family subsistence, supplemented by a cash crop (USAID 2003). *Macrobrachium rosenbergii* species has been cultured in the integrated rice-prawn system since the 1980s in Mekong Delta of Vietnam (Hien *et al.* 1998). Rice-prawn culture can generate higher income than traditional rice-fish culture, because of the higher price of prawns (New 1995). The flooded rice field is a temporary aquatic environment subject to large variations in temperature, pH, dissolved oxygen concentration and nutrient status due to frequent disturbances through practices such as the use of agrochemicals (Watanabe and Roger 1985). From an aquacultural point of view, the rice field is not very suitable for fish production: dissolved oxygen and temperature values often exceed the fish tolerance limits and application of N-fertilizers can result in short term exposures of fish to unionized ammonia (Rothuis 1998).

Fish culture as an integrated and concurrent activity with rice culture in the same field is important for rational utilization of limited land resources, as well as a sustainable source of fish protein, additional income, and employment generation (Sollows and Thongpan 1986 and Ghosh 1992). Lightfoot *et al.* (1992) summarized rice yield data from 20 rice-fish systems from China, India, Indonesia, the Philippines and Thailand and found that rice yields ranged from 58 to 183% as compared to rice monoculture. Gupta (1998) conducted a survey on 256 farms in Bangladesh to assess the feasibility and economic viability of rice-fish culture. They found an average fish production of 233 kg/ha in the dry season and 212 kg/ha in the rainy season, and an average increase in the net benefit by 64.4% and 98.2% compared to rice monoculture, respectively. Frei *et al.* (2007) obtained the highest yield (586 kg/ha) in the carp/tilapia mixed culture followed by tilapia alone (540 kg/ha) and carp alone (257 kg/ha) in the rainy season and in the winter season, the highest yield (935 kg/ha) obtained in feed level II followed by feed level I (776 kg/ha) and the non-fed group (515 kg/ha).

Materials and methods

Experimental Site

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh during rainy season from July to November, 2007. The experimental site is under the old Brahmaputra Flood Plain Agro-ecological Zone having non-calcareous dark grey soils of silt loam texture and was situated in a relatively low land area near the deep tube-well of the field laboratory having 0.2 ha in size. The experimental area was divided into 15 plots, each comprising an area of 142 m^2 having rectangular in shape. Small water channels (70 cm width and 30 cm depth) were made between the plots to supply water in the experimental plots. Rainwater and irrigation water from the farm deep tube-well were the sources of water supply to the experimental plots. Each plot had common inlet and outlet in the dikes (height 60 cm, base width 50 cm and top width 40 cm) for regulation of water depth.

Nylon nets were fixed around each plot with the help of bamboo poles to prevent the entry of unwanted animals in the plot and escapement of stocked fish.

Experimental design

The experiment was conducted in a randomized complete block design (RCBD) with five treatments and three replications for each treatment. The treatments were: rice combined with fish having regular urea fertilization treatment I (T_1), rice combined with prawn having regular urea fertilization treatment II (T_2), rice combined with fish having supplementary feeding treatment III (T_3), rice combined with prawn having supplementary feeding treatment IV (T_4) and Treatment V (T_5) was kept as control i.e., without fish and prawn.

Field management

The experimental plots were ploughed two times using a power tiller. The weeds were removed and the land was then leveled by laddering. A small refuge pond was excavated in the middle of each plot, covering an area of 3 m^2 with 0.5m depth to provide shelter for fish during low water level and high temperature.

A basal dose of fertilizer was applied one day before transplanting according to the recommended dose BRRI (2004), i.e. 150 kg/ha triple super phosphate (TSP) and 75 kg/ha muriate of potash (MP). Urea was applied according to the BRRI (2004), i.e. 220 kg/ha in the T_1, T_2 and T_5 in three installments at 15, 30 and 55 days after transplanting (DAT) of rice seedlings with one-third of the total dose during each application.

The seedling of BR 11 were transplanted into the experimental plots at 48 days after seeding (DAS) in alternate row spacing of 35 cm and 15 cm as suggested by Hossain *et al.* (1990). The plant to plant distance in the rows was 20 cm. The alternate row spacing provides enough space for easy movement of fish and to penetrate sunlight in the water between the rows which improves the growth of plankton for fish feed.

Stocking and management of fish and prawn

The fingerlings of monosex tilapia (*Oreochromis niloticus*), common carp (*Cyprinus carpio*) and juvenile of prawn (*Macrobrachium rosenbergii*) were released in the experimental plots at 28 DAT and stocked at a density of 1 fish/m^2 and 2 prawns/m^2 respectively. Fish species were stocked at a ratio of 1:1. The fingerlings and juveniles were kept in a bucket in the experimental plots for about 15 minutes to adjust with the new environment. The healthy and strong fingerlings and juveniles were then gradually released into the central ditches. The average initial weight of fish and prawn were recorded at the time of stocking and they were 10.49 g and 1.5 g respectively.

Management of fish and prawn

Feeding was started five days after stocking. The feed ingredient were thoroughly mixed and made into 4 mm pellets. The feed composition was 50% fish meal, 44% wheat flour, 4% soybean oil and 2% mineral and vitamin premix. The proximate composition of feed on a dry matter (DM) basis was 34.9% crude protein, 12.7% crude lipid, crude ash

13.4% and gross energy19.5 kJ/g. Feed was provided to the fish @ 6.4 g of feed per kg metabolic body mass per day (g $kg^{-0.8}$/day) at 2 x maintenance feeding according to Becker *et al.* (1983). Feed was provided manually daily at 9 am. Feeding level was adjusted fortnightly based on the prospective fish biomass assuming a metabolic growth rate of 8 g $kg^{-0.8}$ /day (Frei and Becker 2005). The total amount of feed supplied was 6.5 kg (DM) in each plot. Water was supplied to the plots from the deep tube well and water level was raised gradually ranging from 15-25 cm with the growth of rice and fish.

For prawn feed was made into 3 mm pellets. The feed composition was 20% fish meal, 20% wheat flour, 10% meat and bone meal, 20% rice bran, 10% mustard oilcake, 15% soybean meal, 4% molasses and 1% mineral and vitamin premix *(Bright Fish Premix*, Anivet Agro Products Ltd.). The proximate composition of feed on a dry matter (DM) basis was 23.5 % crude protein, 9.4 % crude lipid, crude ash 12.3% and gross energy17.4 kJ/g. Feed was provided daily at 5 pm. Feeding level was adjusted fortnightly based on the sampling.

Water quality parameters

Water temperature, pH and dissolved oxygen levels were recorded weekly at 8 am and 3 pm using electronic probes and a portable multi-parameters instrument (Multi 340i, WTW, Weilheim; Germany). In addition, chlorophyll-a level was analyzed using the acetone extraction method (90% concentration) with cellulose nitrate filters (Whatman GF/C). Further water samples were taken fortnightly and analyzed for nitrate, ammonia and phosphate contents by using spectrophotometer (HACK-USA, DR 2010) and reagent of mineral stabilizer, polyvinyl alcohol, nessler for ammonia and pillow NitraVer 6, NitriVer 3 for nitrate and phosVer 3 for phosphate. These analyses were also done in duplicate.

Harvesting of rice, fish and prawn

Rice was harvested plot-wise at 125 DAT by cutting the plants at the water level with sickle. For determining rice yields, five samples were taken from each plot randomly placing a 1 m^2 frame and cutting the rice plants inside the frames at soil level. The rice sampled was threshed out manually. The grains were then cleaned and sun dried and weighed. Representative samples were taken for determination of the dry matter by drying overnight in a laboratory oven at 105 ^{o}C. The straw was also sun dried and the moisture content was determined. The yield data of grain and straw were then adjusted into mt/ha at 14% moisture level.

Fish and prawn including weed fish were harvested immediately after rice harvesting, i.e. 98 days after stocking fish fingerlings and prawn juveniles. The fish and prawn were collected from each experimental plot manually after draining out the water from the plots. They were then counted and weighed plot and species wise.

Data Analysis

Data are presented as mean values ± standard deviations. Mean values were compared by performing one way analysis of variance (ANOVA), followed by LSD test to detect statistically significant differences between the treatments at $p<0.05$. The software used for statistical analyses was SPSS, Version 11.5 for MS Windows (Chicago USA).

Results

Water quality parameters in rice fields

The water temperature during the experimental period was more or less similar in all treatments (Table 1). Temperature showed weekly variations in all the treatments with more or less continuous decreasing trend towards the end of the experiment. There was no significant difference in morning and afternoon pH values among the treatments. The values of dissolved oxygen in morning were higher in prawn containing treatments and control than the fish containing treatments. The highest mean value of morning dissolved oxygen was recorded in T_2 and the lowest of the same was recorded in the treatment T_1. The highest afternoon of the same was recorded in the treatment T_2. The dissolved oxygen values obtained in treatments with fish both in morning and afternoon were lower than the values of prawn containing treatments and control. The highest mean value of nitrate- nitrogen (NO_3-N) was recorded in the treatment T_1 and the lowest of the same was recorded in the treatment T_4. In prawn containing treatments the NO_3-N value was lower than the fish containing treatments and control. The mean values of phosphate-phosphorus (PO_4-P) was significantly higher ($p<0.05$) in T_1 than the values of other treatments except in T_3 where difference was not significant. The mean value of ammonium-nitrogen (NH_4-N) was significantly higher ($p<0.05$) in T_1 than the values recorded in T_2 and T_4 and no such difference was observed with the rest of the treatments. However the lowest value was obtained in T_4. The highest concentration of chlorophyll-a was obtained in the treatment T_3 that was closely followed by the value of T_1. However the values of chlorophyll-a were higher in fish containing treatments than the prawn containing treatments and control.

Table 1. Mean values of water quality parameters recorded in different treatments during the experimental period

Parameters	Treatments				
	T_1	T_2	T_3	T_4	T_5
Temperature am (°C)	26.5 ± 1.9^{a}	27.1 ± 2.1^{a}	26.5 ± 2.2^{a}	26.5 ± 2.1^{a}	26.4 ± 1.9^{a}
Temperature pm (°C)	28.7 ± 2.5^{a}	28.9 ± 3.1^{a}	28.7 ± 2.9^{a}	28.9 ± 3.2^{a}	28.5 ± 2.7^{a}
pH am	7.0 ± 0.4^{a}	7.2 ± 0.5^{a}	7.1 ± 0.4^{a}	7.1 ± 0.4^{a}	7.0 ± 0.3^{a}
pH pm	7.3 ± 0.5^{a}	7.5 ± 0.6^{a}	7.4 ± 0.6^{a}	7.4 ± 0.6^{a}	7.6 ± 0.4^{a}
DO am (mg/l)	4.1 ± 2.1^{b}	5.3 ± 2.7^{a}	4.3 ± 2.6^{b}	4.7 ± 2.4^{ab}	5.1 ± 2.4^{a}
DO pm(mg/l)	6.1 ± 3.3^{b}	8.3 ± 3.2^{a}	6.1 ± 3.2^{b}	7.1 ± 2.7^{ab}	7.8 ± 3.1^{a}
NO_3-N (mg/l)	0.63 ± 0.30^{a}	0.36 ± 0.54^{b}	0.58 ± 0.48^{a}	0.31 ± 0.26^{b}	0.40 ± 0.40^{ab}
PO_4-P (mg/l)	0.26 ± 0.30^{a}	0.08 ± 0.06^{b}	0.20 ± 0.10^{ab}	0.09 ± 0.11^{b}	0.1 ± 0.1^{b}
NH_4-N (mg/l)	0.35 ± 0.21^{a}	0.22 ± 0.18^{b}	0.30 ± 0.23^{ab}	0.18 ± 0.07^{b}	0.28 ± 0.25^{ab}
Chlorophyll-a (μg/l)	36.4 ± 8.7^{ab}	23.3 ± 9.1^{b}	41.5 ± 10.6^{a}	22.3 ± 7.8^{b}	25.3 ± 8.9^{b}

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

Survival rate of fish and prawn

The survival rate of fish and prawn were estimated separately and treatment-wise from the harvesting data and shown in Table 2. The average survival rate of common carp was higher than the average survival rate of tilapia. In fish containing treatments, the treatment-wise survival rate was higher in T_3 (87±6%) than the T_1 (52±7%). In prawn containing treatments, the survival rate were very low and these were 23±14% in T_2 and 39±30% in T_4.

Table 2. Survival rates of fish and prawn in different treatments in rice field

Treatments	Survival rate (%)			
	Tilapia	Carp	Tilapia/Carp	Prawn
T_1	41±17	70±9	52±7	-
T_2	-	-	-	23±14
T_3	83±11	91±2	87±6	-
T_4	-	-	-	39±30

Yield of fish and prawn

Yield of fish and prawn are shown in Table 3. The highest yield (539.44±84.9 kg/ha) was recorded in T_3 than the rest of the treatments. The yield was significantly higher (p<0.05) in treatments with fish than the treatment with prawn. Total gross yield was also significantly higher in the treatments with fish than the treatment with prawn. The yield of weed fish obtained in different treatments was more or less similar.

Table 3. Production and efficiency parameters of fish and prawn in different treatments in rice field

Items	Treatments			
	T_1	T_2	T_3	T_4
Gross yield (kg/ha)	424.88±207.13^a	64.32±38.38^b	539.44±84.94^a	108.69±65.57^b
Net yield (kg/ha)	314.32±222.14^a	30.98±40.86^b	440.14±79.81^a	81.92±62.83^b
Weed fish (kg/ha)	29.58±12.81	29.58±20.86	25.59±12.68	27.23±12.15
Total gross yield including weed fish (kg/ha)	454.46±215.20^a	93.90±40.28^b	565.02±74.15^a	135.91±62.99^b

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

Yield of Grain and Straw

All of the grain and straw yield are shown in Table 4. The highest yield of grain obtained 3.45±0.04 mt/ha in T_1 and the lowest of the same was recorded 2.94±0.49 mt/ha in T_2. No significant difference was observed among the treatments. The highest yield of straw obtained was 6.24±0.13 mt/ha in T_1 and the lowest (5.68±0.33 mt/ha) was recorded in T_5 i.e. control plot. No significant difference was observed among the treatments.

Table 4. Rice yield parameters in different treatments in rice fields

Items	Treatments				
	T_1	T_2	T_3	T_4	T_5
Grain yield (mt/ha)	3.45±0.04	2.94±0.49	3.16±0.10	3.32±0.21	3.01±0.22
Straw yield (mt/ha)	6.37±0.10	6.24±0.22	6.09±0.54	5.91±0.23	5.68±0.33

Values are mean ± standard deviation

Discussion

Temperature of water condition in a rice field is known to be one of the limiting factors for fish productivity. Water temperature in the rice fields fluctuated between 24.20-35.32°C among the different treatments of the present study. Almost similar ranges of water temperature were reported by various authors in rice-fish or prawn culture experiments in Bangladesh (Uddin 1998, Mondol 2001, Das 2002 and Kundu 2003). The pH levels in the rice fields tended to be lower in the presence of fish than in rice grown alone. In the present study, the pH values of water in rice fields ranged between 6.60-7.95, which are almost close to the neutral pH indicating suitable condition for fish and prawn culture. pH values were slightly higher in the afternoon than in the morning. Similar results were reported elsewhere (Rothuis *et al.* 1999, Vromant and Chau 2001, Frei and Becker 2005). Dissolved oxygen (DO) content is probably the single most important water quality parameter in aquaculture. Prolonged exposure to low DO concentration can be harmful for the aquatic life. In the present study, the DO levels of water ranged were between 2.2-8.8 mg/l which are almost similar to the values of 2.3-6.7 and 3.6-8.7 mg/l in rice fields reported by Rothuis *et al.* (1999) and Frei and Backer (2005). Higher values of dissolved oxygen in the afternoon might be associated with the high rate of photosynthesis in presence of sunlight. The high levels of DO in prawn containing treatments and rice only treatment may be attributed to the presence of filamentous algae which were comparatively low in rice-fish plots due to the grazing effect, very turbid water caused by fish specially *C. carpio* and consumption of oxygen by respiration of fish. The values of NO_3-N were also recorded higher in the treatments with fish than without fish which support the findings of Mondol (2001) and Sarker (2005). The phosphate concentration was also higher in the treatments with fish than in control which might be due to accumulation fish faeces and bioperturbation effect of fishes. Sarker (2005) also obtained relatively higher values of it in his study. The phosphate concentration were lower in prawn containing plots might be used phosphorus for their shell formation. Concentration of ammonia showed an increasing trend as the days of culture increased, probably due to higher metabolic deposition and organic load. The range of NH_4-N values recorded by Mohanty *et al.* (2004) in rice fields were 0.01-0.31 mg/l which are lower than the values obtained in the present study. Slight higher values of NH_4-N recorded in the treatments with fish than the control might be associated with the reasons stated above. High filtration rate of tilapia as depicted by Turker *et al.* (2003), which reduces phytoplankton abundance. This is substantiated by the chlorophyll-a values, which were significantly lower in the presence of tilapia as compared to a situation with common carp only. During the study period, the values of chlorophyll-a were found to range between 10.3-61.5 μg/l among the treatments. Higher chlorophyll-a were obtained in treatment with fish might be the effect of organic accumulation due to fish faeces.

Haroon and Pittman (1997) reported survival rates of tilapia 66% in rice field which is more or less similar to the present study. The higher survival rate of tilapia and common carp in T_3 than the T_1 might be due to the use of supplementary feed in this treatment. The survival rates reported by Mondal (2001) for common carp (58%) were lower than the finding of the present study. The combined survival rates of common carp and tilapia obtained were 52% and 87% in T_1 and T_3 respectively. The survival rate recorded by Frei *et al.* (2007) for rice combined with common carp and tilapia (57 %) is lower than the survival rate of the same treatment in the present study. The lowest survival rate of prawn was in T_2 might be due to the absence of supplementary feeding.

The gross and net yield of combined culture of common carp and tilapia recorded by Frei *et al.* (2007) in rice field were 586 kg/ha and 460 kg/ha respectively which were higher than the yield obtained in the present study. Between the two prawn treatments the higher gross (108.69 kg/ha) and net (81.92 kg/ha) were obtained in T_3 with supplementary feeding and lower gross (64.32 kg/ha) and net (30.98 kg/ha) yield were recorded in T_2 without supplementary feeding. The cause of lower yield of prawn might be the lower survival rate of prawn. Sarkar (2006) recorded yield of prawn were 221.98 kg/ha to 388.38 kg/ha in his study that were explicitly higher than the present study.

The highest grain yield (3.45 mt/ha) was obtained in T_1 with fish having urea fertilization without feeding. Frei *et al.* (2007) also obtained the highest grain yield from the similar treatment in their experiment. The yield of rice grain obtained by Frei *et al.* (2007) in their study (3.4 mt/ha and 3.8 mt/ha) are almost similar to the yield of present study. Frei *at el.* (2007) obtained the yield of rice straw 6.2 mt/ha, 5.7 mt/ha, 5.8 mt/ha and 5.7 mt/ha in rice with common carp, rice with tilapia, rice with common carp/tilapia and rice only respectively that are more or less similar to the present study.

According to the findings of present study, it may be concluded that the introduction of fish culture in rice fields has more or less positive impacts on the availability of nitrate-N, ammonia-N, phosphate-P and chlorophyll-a of water. Therefore, this integrated rice-fish culture technology may be recommended for dissemination to the rural poor farmers through extension program which will benefit them economically and nutritionally. Between the treatments with fish and prawn, the treatments with fish may be recommended for dissemination to rural farmers considering higher yields and economic beneficial. Among the treatments the species composition of tilapia (*O. niloticus*) and common carp (*C. carpio*) was found to be most suitable for rice fish culture considering the survival and yield.

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