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# Impacts of different rice-fish-prawn culture systems on yield of rice, fish and prawn and limnological conditions

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## Abstract

An experiment was conducted to determine the impact of fish and prawn culture on some physico-chemical parameters of water, weeds, benthos, and rice yield under simultaneous method for a period of 5 months from July to November 2007. The experiment was comprised of five individual treatments having three replicates for each. The treatments were: rice combined with fish and regular urea fertilization (treatment I, $T_1$), rice combined with prawn and regular urea fertilization (treatment II, $T_2$), rice combined with fish and supplementary feeding (treatment III, $T_3$), rice combined with prawn and supplementary feeding (treatment IV $T_4$) and treatment V ($T_5$) was kept as control i.e., without fish and prawn. The physico-chemical parameters of water were monitored at weekly interval and were within the suitable range for fish culture. Among the treatments evaluated, the highest number of zoobenthos (worms, chironomids) was recorded in $T_5$ without fish (control) and the lower number of the same was obtained in rice-fish culture treatments ($T_1$ and $T_3$) than the other treatments, indicating higher feeding preference of common carp and tilapia on zoobenthos. However, significant abundance of the weed biomass was observed in the rice-prawn farming treatments ($T_2$ and $T_4$) and also in control treatment. The net fish yield in $T_1$, $T_2$, $T_3$ and $T_4$ were 314.32±222.14 kg/ha, 30.98±40.86 kg/ha, 440.14±79.81 kg/ha and 81.92±62.83 kg/ha, respectively. The highest yield was recorded in $T_3$ than the rest of the treatments. The yield was significantly higher in rice-fish treatments than those in the rice-prawn plots. Based on the results of the study, it can be suggested that the treatments with fish may be recommended for dissemination to rural farmers considering higher yields and economic benefits.

**Keywords:** Water quality, Rice-fish and Rice-prawn, Zoobenthos, Weeds, Yields

## Introduction

Land and water resources must be utilized effectively and efficiently through short-term and long-term research and development programs. The area of croplands has already been declined in this country by 3.1% from mid 1980 to mid 1990 (Ahmed *et al*., 1995). These croplands might have decreased further as many of them have been converted to pond for fish culture. Rice and fish are the staple food of the people of Bangladesh, while rice production increased to the same extent due to the over exploitation of natural aquatic resources (Halwart, 1994). Therefore, prime importance should be given to water resources for their judicial exploitation by introducing effective management systems and improved cultural technologies along with integration of crop, animal and fish in closed water resources.

Rice-fish culture has long been recognized as an option to improve the productivity of the country's rice based agriculture. Dewan (1992) estimated that Bangladesh had approximately 2.83 million hectares of rice fields to be suitable for integrated rice-fish production. Gupta *et al*. (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. Lowland rice fields constitute a semi aquatic environment which is suitable for fish production if the water level can be controlled. Integrated rice-fish culture has numerous advantages, including efficient utilization of resources, economic benefits for the farmers, and improvement of food security in rural areas (Frei and Becker, 2005). Apart from these advantages, fish have been proposed to act as biological control agents, potentially controlling insect pests and weeds (Yuan, 1992). This is conceivable as the natural food of species, suitable for rice-fish culture such as common carp, *Cyprinus carpio* L., and Nile tilapia, *Oreochromis niloticus* (L.), often consists of insect larvae and their adults, grass seeds or aquatic flora (Fernando, 1996).

Rice-fish culture may become more attractive to farmers if fish production can be increased through efficient management strategies. The objective of the present study was to assess the impacts of fish and prawn culture in rice fields on some physico-chemical parameters of water, benthos, weeds, and rice yields in integrated culture system.

## Materials and Methods

### Experimental site

The study was carried out from July to November 2006 in the Agronomy Field Laboratory under the Department of Agronomy, Bangladesh Agricultural University, Mymensingh. Fifteen rectangular plots, having an average area of 142 $m^2$ each, were used for this experiment. Water channels (70 cm width and 30 cm depth) were constructed between the plots to supply water in the experimental plots. A small ditch was excavated in the middle of each rice plot, covering an area of 3 $m^2$ with an average depth of 0.5 m to provide shelter for fish and prawn during low water level and high temperature. Embankments (1.0 m height and 0.50 m width) were constructed surrounding the experimental plots, which made them free from flood. Each dyke had a common inlet and outlet for regulation of water depth. Nylon nets were fixed around each plot with the help of bamboo splits to prevent the entry of unwanted animals in the plot and escapement of stocked fish.

### Experimental design

The experiment was consisted of five individual treatments having three replicates for each. The treatments were laid out in a randomized complete block design (RCBD). The treatments were: rice combined with fish and regular urea plus other fertilization ( treatment I, $T_1$), rice combined with prawn and regular urea plus other fertilization ( treatment II, $T_2$), rice combined with fish and supplementary feeding without fertilization ( treatment III, $T_3$), rice combined with prawn and supplementary feeding without fertilization (treatment IV $T_4$) and treatment V ($T_5$) was kept as control i.e., without fish and prawn but with urea plus other fertilization. The design and layout of the experiment are shown in Table 1.

**Table 1. Design and layout of the experiment**

| Treatments | Combinations of rice, fish & prawn | Inputs | |
|---|---|---|---|
| | | Feed | Fertilizer |
| $T_1$ | Rice + Fish | - | Urea, TSP& MP |
| $T_2$ | Rice + Prawn | - | Urea, TSP& MP |
| $T_3$ | Rice + Fish | Feed | TSP& MP |
| $T_4$ | Rice + Prawn | Feed | TSP& MP |
| $T_5$ | Rice only | - | Urea, TSP& MP |

### Field management

The plots were ploughed two times before the transplantation of rice using a power tiller and the soil was leveled using a locally common hand-drawn bamboo-leveler. The rice variety BR-11 was selected for this experiment. Rice seeds were soaked into water for 24 hours, pre-germinated, and broadcast into a nursery field. Rice seedlings were then transplanted into the experimental plots after 48 days of seeding. Rice seedling was transplanted at alternate spacing of 15 and 35 cm between the rows and 20 cm within the rows, with 2-3 seedlings per hill. The alternate rice spacing has the advantage of allowing more light to penetrate the water surface, which enhances photosynthesis and dissolved oxygen concentration. Rice seedlings were allowed to establish at a shallow water level of less than 5 cm before the stocking of fish.

The fish fingerlings and prawn juveniles were released in the experimental plots at 27 and 28 DAT stocked at a density of 1 fish per $m^2$ and 2 prawns per $m^2$, respectively. Fish species and shrimp) were mixed 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 at stocking were 10.49 g and 1.5 g, respectively.

### Fertilization

Fertilizers were applied in each plot one day (3-4 day) before transplanting according to the recommended dose of BRRI (2004), i.e.,150 kg/ha, 75 kg/ha and 220 kg/ha of triple super phosphate (TSP), muriate of potash (MP) and urea) in $T_1$, $T_2$ and $T_5$, respectively. The total amount was applied in three installments at 15, 30 and 55 days after the transplantation (DAT) of rice seedlings with one-third of the total dose during each application.

### Management of fish and prawn

Feeding was started five days subsequent to stocking. The ingredients were thoroughly mixed and made into 3 mm pellets using a pelletizing machine. The fish feed was comprising of 50% fish meal, 44% wheat flour, 4% soybean oil and 2% mineral and vitamin premix. The proximate composition of fish 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. The prawn feed was consisting of 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. The proximate composition of prawn feed on a dry matter (DM) basis was 23.5 % crude protein, 9.4 % crude lipid, crude ash 12.3% and gross energy 17.4 kJ/g. Fish and prawn feeds were provided manually daily at 9.00 am and 5.00 pm, respectively. The feeding rate was adjusted at fortnightly sampling of fishes. After stocking of fishes, water depth in rice fields was kept at a level of 15 to 25 cm throughout the experiment.

### Physico-chemical parameters of water

The water quality parameters such as temperature, pH, dissolved oxygen, nitrate-nitrogen, phosphate-phosphorus, ammonia-nitrogen, and chlorophyll-a were estimated weekly following the Standard Method by APHA (1992).

### Collection of weeds and zoobenthos

Weeds were collected manually from all the rice plots at 37 and 78 DAT of rice seedlings. Collected weeds were washed and sun dried at least for 1 day and then the weight of dry weeds was taken. Benthic organisms were collected at 39, 79 and 113 DAT of rice seedlings using an Ekman dredge. The soil samples were flushed through a 0.2 mm sieve and analyzed immediately. Benthic organisms were identified in the laboratory using magnifying glass and compound microscope.

### Harvesting and determination of growth and yield

Rice was harvested plot-wise at 125 DAT by cutting the plants at the water level. The rice grains were sun dried and representative samples were taken for the determination of dry matter by drying overnight in a laboratory oven at 105 ºC. The straw was also sun dried for the determination of moisture content.. Fish and prawn were harvested immediately after the complete harvesting of rice followed by draining out the water from the experimental plots. Most fish were collected from the refuge pond and the remaining fish were hand-picked from the drained plot surfaces. Fish and prawn were counted and weighed plot wise and growth in term of *metabolic growth rate* (MGR, g $kg^{-0.8}$ $d^{-1}$) was calculated according to the following formula:

$$MGR = [(M_f - M_i) / ((M_f + M_i) / 2000)^{0.8})] / D$$

Where, $M_f$ is the final fish body mass (g), $M_i$ is the initial fish body mass (g), and D is the duration of the experiment (days).

### Data analysis

Comparison of mean values was done by t-test and one way-analysis of variance (ANOVA), followed by Duncan's multiple range test at a significance level of $p<0.05$ (Gomez and Gomez, 1984).

## Results and Discussion

### Water quality parameters in rice fields

The water quality parameters such as temperature, pH and dissolved oxygen fluctuated from 24.20-35.32°C, 6.60-7.95 and 3.6-8.7 mg/l, respectively in the rice fields during the experimental period. Das (2002) and Kundu (2003) reported almost similar ranges of water quality parameters in their rice-fish culture plots. However, the above parameters in the rice fields were within the suitable range for fish and prawn culture. The dissolved oxygen concentration was higher in rice-prawn and control treatment (rice alone) than rice-fish culture treatments. The high levels of DO in prawn culture and control plots might be attributed to the presence of filamentous algae, which were comparatively low in rice-fish treatments due to the grazing effect, very turbid water and consumption of oxygen by respiration of fish.

In the present study, the ranges of nitrate-nitrogen, phosphate-phosphorus and ammonia-nitrogen concentrations were obtained to be 0.12-0.88 mg/l, 0.02-0.36 mg/l and 0.07-0.55 mg/l, respectively. Higher nitrate-nitrogen values were recorded in $T_1$, $T_3$ and $T_5$, might be the due to application of urea fertilizer in these treatments. The phosphate concentration were lower in rice-prawn treatments ($T_2$ and $T_4$) might be due to utilizing phosphorus for their shell formation. Concentration of ammonia-nitrogen showed an increasing trends as the days of culture increased, probably due to higher organic decomposition and organic load. Azim *et al.* (1995) stated that near about 0.5 mg/l nitrate-nitrogen was suitable for fish culture.

During the study period, the values of chlorophyll-a were found to range between 10.3 and 61.5 µg/l among the treatments. Frei and Becker (2005) recorded chlorophyll-a concentrations ranged from 10 to 90 µg/l in rice-fish farming plots. Higher chlorophyll-a values obtained in fish culture plots might be due to lower grazing pressure of fish on phytoplankton.

**Table 2. Mean values (±SD) of water quality parameters of weekly samples recorded in different treatments during the experiment**

| Parameters | Treatments | | | | |
|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| Temperature (°C) am | $26.5±1.9^{a}$ | $27.1±2.1^{a}$ | $26.5±2.2^{a}$ | $26.5±2.1^{a}$ | $26.4±1.9^{a}$ |
| Temperature (°C) pm | $28.7±2.5^{a}$ | $28.9±3.1^{a}$ | $28.7±2.9^{a}$ | $28.9±3.2^{a}$ | $28.5±2.7^{a}$ |
| 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 (mg/l) am | $4.1±2.1^{b}$ | $5.3±2.7^{a}$ | $4.3±2.6^{b}$ | $4.7±2.4^{ab}$ | $5.1±2.4^{a}$ |
| DO (mg/l) pm | $6.1±3.3^{b}$ | $8.3±3.2^{a}$ | $6.1±3.2^{b}$ | $7.1±2.7^{ab}$ | $7.8±3.1^{a}$ |
| $NO_3$-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 are significantly different ($P<0.05$)

### Weeds

The biomass of weeds, collected at 37 and 78 DAT (day after transplanting) of rice seedling is shown in Table 3. Significantly lower quantity of aquatic weeds was obtained in treatments with fish ($T_1$ and $T_3$) than treatments with prawn ($T_2$ and $T_4$) and in control, might be attributed to the higher grazing activity of fish on weeds. Rothuis *et al.* (1999) reported a decrease in weed abundance by 30% if common carp were cultured alone in rice field and a reduction of weeds increased from 40 to 47% when common carp and Nile tilapia were cultured together. The lower quantity of aquatic weeds obtained in the treatment of rice with fish ($T_1$) receiving urea fertilizer ($T_1$) than the other treatments might be due to higher feeding pressure of fish on weeds and the absence of supplementary feeding. The higher quantity of aquatic weeds in treatments with prawn might be due to lower feeding preference of weeds by prawn.

**Table 3. Comparisons of mean values (±SD) of dry matter of weeds (g/m$^2$) under different treatments in rice fields**

| DAT | Treatments | | | | |
|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| 37 | 2.2±3.4$^b$ | 11.2±9.6$^a$ | 3.3±5.1$^b$ | 7.1±18.2$^{ab}$ | 9.5±15.3$^a$ |
| 78 | 0.2±0.4$^b$ | 5.2±6.8$^a$ | 0.4±0.51$^b$ | 4.3±4.2$^a$ | 5.3±6.6$^a$ |
| Total | 2.4±2.6$^b$ | 16.4±15.5$^a$ | 3.7±4.1$^b$ | 11.4±10.5$^a$ | 14.8±17.4$^a$ |

Mean values with different superscripts in the same row are significantly different (*P<0.05*)

### Zoobenthos

Zoobenthos collected at 39, 79 and 113 DAT of rice seedling is presented in Table 4 and 5. Among the treatments, the highest number of zoobenthos (worms and chironomids) was recorded in $T_5$ (control treatment) and the lower number of the same was obtained in rice-fish treatments ($T_1$ and $T_3$) than those in the other treatments indicating higher feeding preference of common carp and tilapia on zoobenthos. Frei *at el.* (2007) reported that common carp, being a bottom feeder, was more efficient in controlling the benthic fauna than tilapia, which is mainly a column feeder. Ali (1985) reported that about 80% of the total food items of bottom feeder fish are benthic organisms, especially some arthropods larvae and annelids i.e. Oligochaetes as well as small molluscs. The major groups of benthic fauna recorded during the present study were Oligochaeta and Chironomidae. The dominance of these groups of macrobenthos has been reported earlier by Shami and Jafri (1994) and Ignat *et al.* (1994) in the tropical freshwater pond and Delta Lake, respectively. The possible reason for the occurrence of these groups of benthic fauna might be due to the favourable ecological condition prevailed in the rice field for their growth and development.

**Table 4. Comparisons of mean number ((±SD) of zoobenthos (worms) under different treatments in rice fields**

| DAT | Treatments | | | | |
|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| 39 | 13±6.9 | 16.3±5.8 | 12.3±6.7 | 15.7±10.7 | 32±12.8 |
| 79 | 1.7±1.5$^b$ | 4.3±3.5$^a$ | 2.1±1.5$^b$ | 9.0±8.9$^a$ | 9.3±4.7$^a$ |
| 113 | 0.5±0.6$^b$ | 7.7±5.5$^a$ | 0.7±1.2$^b$ | 9.3±3.8$^a$ | 12.0±11.4$^a$ |

Mean values with different superscripts in the same row are significantly different (*P<0.05*)

**Table 5. Comparisons of mean number (±SD) of zoobenthos (chironomids) under different treatments in rice fields**

| DAT | Treatments | | | | |
|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| 39 | 2.4±2.2 | 3.7±2.9 | 2.3±2.1 | 3.3±2.1 | 4.7±2.5 |
| 79 | 0.3±0.6$^b$ | 2.7±0.6$^a$ | 1.0±1.7$^b$ | 5.3±6.1$^a$ | 8.0±1.7$^a$ |
| 113 | 1.3±1.5$^b$ | 7.0±1$^a$ | 1.7±0.6$^b$ | 3.7±2.5$^{ab}$ | 5.3±4$^a$ |

Mean values with different superscripts in the same row are significantly different (*P<0.05*)

### Metabolic growth rate

The highest metabolic growth rate 7.84 g kg$^{-0.8}$/day was recorded in $T_1$ with rice and fish having urea fertilization without feeding while, the lowest 6.06 g kg$^{-0.8}$ /day of the same was recorded in $T_2$ with rice and prawn having urea fertilization without feeding. The metabolic growth rate (8.3 g kg$^{-0.8}$ /day) in rice-fish culture plots with common carp and tilapia recorded by Frei *et al.* (2007) was higher than the growth rate obtained in the present study.

### Yield of fish and prawn

Between the two integrated rice-fish treatments, the higher gross (539.44 kg/ha) and net (440.14 kg/ha) yields were obtained in $T_3$ with supplementary feeding and the lower gross (424.88 kg/ha) and net (314.32 kg/ha) yields were recorded in $T_1$ without supplementary feeding (Table 8). The gross and net yields recorded from the combined culture of common carp and tilapia 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 rice-prawn treatments, the higher gross (108.69 kg/ha) and net (81.92 kg/ha) yields were obtained in $T_4$ with supplementary feeding and lower gross (64.32 kg/ha) and net (30.98 kg/ha) yields were recorded in $T_2$ without supplementary feeding (Table 8). The reason for lower yield might be due to the lower survival rate of prawn in this treatment. Siddik *et al*. (2008) recorded 221.98 kg/ha to 388.38 kg/ha of prawn yield in their study which were much higher than those of the present study.

**Table 6. Production and growth parameters (mean ±SD) of fish and prawn under different treatments in rice fields**

| *Parameters* | Treatments | | | |
|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ |
| Metabolic growth rate (g $kg^{-0.8}$ $d^{-1}$) | 7.84±1.90 | 6.06±0.22 | 7.57±0.56 | 6.70±0.94 |
| 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 in the same row are significantly different ($P<0.05$)

### Yield of rice grain and straw

Rice yield parameters in different treatments in rice fields are presented in Table 9. The highest grain yield (3.45 mt/ha) was obtained in $T_1$ with fish having urea fertilization without feeding. The yield of rice grain (3.4 mt/ha) obtained by Frei *et al.* (2005) in their study, is almost similar to that of present study. The highest straw yield (6.37 mt/ha) also obtained in $T_1$ with fish having urea fertilization without feeding and the lowest (5.68 mt/ha) was in $T_5$ without fish (control). Frei *et al.* (2007) obtained the yield of rice straw as 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 and tilapia, and rice alone treatments, respectively, which are almost similar to those of the present study. The highest total biomass yield (9.82 mt/ha) was obtained in $T_1$ and the lowest of the same (8.70 mt/ha) was obtained in $T_5$ without fish. Frei *et al.* (2007) obtained the total biomass of 9.8 mt/ha, 9.5 mt/ha, 9.6 mt/ha and 9.3 mt/ha in rice with common carp, rice with tilapia, rice with common carp and tilapia, and rice only treatments, respectively, which are also very close to the findings of the present study.

**Table 7. Rice yield parameters (mean ±SD) under different treatments in rice fields**

| *Parameters* | 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 |
| Total biomass yield (mt/ha) | 9.82±0.12 | 9.17±0.68 | 9.25±0.64 | 9.23±0.44 | 8.70±0.12 |

Based on the results of the present study, it can be suggested that the treatments with fish may be recommended for dissemination to rural farmers considering higher yields and economic benefits than those obtained in the treatments with prawn. It can also be recommended that fish with regular feeding is more economic and beneficial than the fish with urea fertilization in integrated rice-fish culture system.

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