Effect of different stocking densities on the gross production and economic yields of prawn (*Macrobrachium rosenbergii*) with mola (*Amblypharyngodon mola*) fish in rice fields

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***Abstract*—**A field experiment was conducted at Shahpur, Dumuria, Khulna to evaluate the effects of stocking densities on the gross production and economic yields of prawn (*Macrobrachium rosenbergii*) in rice fields with mola (*Amblypharyngodon mola*) from 2 August to 30 November, 2014 in 12 experimental rice plots (ghers). Each of four treatments with three replicates was tested in this trial. In all treatments, *M. rosenbergii* was stocked with *A. mola*. The stocking densities of *M. rosenbergii* were 10,000, 15,000, 20,000 and 25,000 individuals/ha in treatments T_1, T_2, T_3 and T_4, respectively. The stocking density of *A. mola* was the same (20,000 individuals/ha) in all the treatments. The mean values of water quality parameters viz., temperature, dissolved oxygen (DO), pH, alkalinity, ammonia, nitrate-nitrogen and phosphate-phosphorus were within the suitable range for fish culture. All rice plots were fertilized with urea (200 kg/ha), TSP (150 kg/ha) and MP (75 kg/ha). At harvesting, prawn and mola in T_2 showed higher growth performances where the stocking densities were 15,000 and 20,000 individual/ha, respectively. The survival was the highest in T_2 (49.65%) followed by T_1 (44.25%) and T_4 (43.55%) and the lowest in T_3 (39.58%). The highest production of prawn was recorded as 386.20 kg/ha (economic values of which was BDT 386200), whereas the mola was 70.68 kg/ha (with the economic value of BDT 10,602) in treatment T_2 than those of other treatments. In case of rice production, comparatively high economic returns (BDT 77,200 from rice and BDT 5,085 from straw) were obtained in T_2 than those in other treatments. The highest net-benefit (BDT/ha) was obtained in T_2 (309,487), followed by T_1 (201,754) and T_3 (164,841) and the lowest in T_4 (108,308). The benefits-cost ratio (BCR) was also higher in T_2 (2.82) than those in T_1 (2.59), T_3 (1.69) and T_4 (1.36), respectively. With respect to growth, production, benefits and BCR, it is indicated that the culture of *M. rosenbergii* in combination with *A. mola* at stocking densities of 15,000/ha and 20,000/ha, respectively were more profitable than those obtained from other stocking densities. The study therefore, established the fact that polyculture of freshwater prawn and mola is a better composition for rice-fish culture in Bangladesh.

Keywords*—Macrobrachium rosenbergii*, *Amblypharyngodon mola*, Stocking density, Rice fields, Production, Economic yields.

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I. Introduction

BANGLADESH is among the most densely populated countries in the world, having more than 985 inhabitants per km^2. According to United Nations projections, the population will grow further to 1687 inhabitants per km^2 by the year 2050. Providing sufficient food for the counties vast population will put increasing pressure on Bangladesh's scarce natural resources. Especially water and land need to be utilized more efficiently due to the development of the population and the rise of other sectors of the economy competing with agriculture for resources. In fact cropland has already declined in Bangladesh by 3.1 percent from the mid-1980s to the mid-1990s [1]. Efficient utilization of resources in agricultural production is therefore, of utmost importance to ensure food security in Bangladesh.

Rice-fish culture has long been recognized as an option to improve the productivity of the country's rice-based agriculture. Dewan [2] estimated approximately 2.83 million hectares of rice fields, which are suitable for integrated rice-fish farming in Bangladesh. However, he noted that much research remains to be done to optimize the management of such systems in order to make them more profitable for the farmers. A survey was conducted on 256 farms in Bangladesh to assess the feasibility and economic viability of rice-fish culture [3]. 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. A number of field experiments were carried out in Bangladesh under defined conditions. The suitability of the small indigenous species, for example, *Amblypharyngodon mola* was tested for production in rice yields [4] and obtained a maximum fish yield of 262 kg/ha. In another study, silver barb (*Barbonymus gonionotus*) and Nile tilapia (*Oreochromis niloticus*) were cultured and obtained a fish production of 271 kg/ha and a rice yield of 1.5–3.7 t/ha [5]. In all studies known from Bangladesh so far, the fish yields were moderate as compared to the generally accepted production potential of 200 to 700 kg/ha [6].

Integration of rice with fish farming may become more

attractive for farmers if fish production can be increased through efficient management strategies. Therefore the objective of the current study was to assess the gross production and economic yields at different stocking densities of prawn (*Macrobrachium rosenbergii*) with mola (*Amblypharyngodon mola*) fish in the same rice fields through proper integrated culture management.

II. MATERIALS AND METHODS

A. Site selection

The experiment was carried out from July to November 2006 in a village of Shahpur at Dumuria under Khulna district. Twelve rectangular plots having an average area of 152 m^2 each were used for this experiment. The only sources of water were rain for the experimental plots. The embankments (1.0 m height and 0.5 m width) were constructed surrounding the experimental plots and were made free from flood and escaping of fish or prawn. Fencing by plastic nets (0.5 m height) was provided around the experimental areas to prevent the stocked prawn from escaping.

B. Experimental design

The experiment was designed into completely randomized design (CRD) with four treatments having three replicates for each. The stocking density of *M. rosenbergii* were 10,000, 15,000, 20,000 and 25,000/ha in T_1, T_2, T_3 and T_4, respectively. The stocking density of A. *mola* was the same (20,000/ha) in all the treatments.

C. Construction of ditches

A small ditch was constructed in the middle position in each plot covering an area of 2.0 m^2 with 0.50 m depth. This ditch provides shelter for mola and prawn during low water level and high temperature.

D. Fertilization

In order to increase the farm productivity, all the experimental plots were fertilized with urea, triple super phosphate (TSP) and murate of potash (MP) at the rate of 200, 150 and 75 kg/ha, respectively recommended by BRRI [1].

E. Rice variety and rice transplantation

Rice seedlings were transplanted during July-August, following normal agronomy practices. Among the rice varieties BR-22 (HYV) was transplanted due to its short culture period (105-125 days), medium height, high resistance to insect and disease infestation and highest yield performances.

F. Collection and stocking of fish

The juvenile of *M. rosenbergii* and *A. mola* were collected from local private nursery. The juveniles were released after 18 days of transplanting rice by which time rice plants must have well established. After stocking, water depth in rice fields was kept at a level of 15 to 25 cm throughout the experimental period.

G. Rice-fish culture management

For proper management of rice field, all the activities including fertilization were done according to the normal agronomy practices, recommendation by the Farming System and Environmental Studies (FSES) of Bangladesh Agricultural University, Mymensingh. Feeding was started five days after stocking at the rate of 6-3% of estimated body weight once daily. The diet was comprised of 50% fish meal, 44% wheat flour, 4% soybean oil, and 2% mineral and vitamin premix. Feed was provided manually once daily between 9.00 and 10.00 h. The feeding rate was adjusted at fortnightly sampling of fishes. Sampling was done at monthly interval to observe the growth and health condition of fish as well as to adjust the feed requirements for the subsequent months.

H. Water Quality Parameters

(1) Physico-chemical parameters of water viz., temperature, transparency, dissolved oxygen, pH, alkalinity, ammonia, nitrate-nitrogen, phosphate-phosphorus and chlorophyll-a were monitored fortnightly between 09.00 and 10.00 h following the standard method [7].

I. Harvesting of rice and fish

After 132 days of transplantation, rice was harvested by cutting the plants at ground level with sickle. The representative samples of rice were taken randomly from each plot comprising of an area of 1 m^2. The weights of dried grain and straw were recorded separately from each plot. Immediately after harvesting, most fishes were collected from the refuge ditch and the remaining was hand-picked from the drained plot surface. The collected prawns and mola from the plots were counted and the number was recorded separately. The final length (cm) and weight (g) of each species were taken randomly from each plot to determine the growth rate and yield of prawns and mola. Total counts of each species were recorded to determine the survival rate of each species.

J. Data Analysis

The data obtained from the experiment were analyzed using one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test [8−10]. A simple cost-benefit analysis was conducted to estimate the net benefits from each treatment.

III. RESULTS AND DISCUSSION

A. Water quality parameters

The values of water quality parameters from the rice fields under different treatments are shown in Table 1. In the present study, mean values of water temperature in the rice fields have been fluctuated between 29.82 and 30.62^0C. Almost similar ranges of water temperature were reported by various authors in rice-fish culture plots in Bangladesh [11−13]. The mean values of water pH ranging from 7.72 to

7.84 are almost closer to the neutral pH, indicating a suitable condition for fish culture. Similar results were also reported elsewhere [6, 14, 15]. The DO levels of water ranged from 4.83 to 5.41 mg/l are similar to the values of 3.6 to 8.7 mg/l in rice fields as reported by Frei and Backer [6]. A drop in pH or DO values may be explained by reduced photosynthetic activity in the water due to fish grazing on aquatic flora. In the study, the mean values of alkalinity ranged between 13.88 and 65.38 mg/l. Rahman et al. [16] found the total alkalinity ranged from 64.85 to 85.36, which is strongly supported this result. The growth of phytoplankton seems to be stimulated by the presence of fish, as reflected in the chlorophyll-*a* values, although not so pronounced in T_4. Such an effect was also observed in previous studies on rice-fish ecology, e.g. Vromont and Chau, [15]. As with chlorophyll-*a* water, nitrogen and phosphorous concentrations tended to be elevated in the T_1, T_2 and T_3 compared to T_4. This may either be due to mineralization and diffusion of soil nutrients [15] or excretion of unutilized feed nutrients by fish.

TABLE 1. THE MEAN ± SE VALUES OF DIFFERENT WATER QUALITY PARAMETERS IN THE EXPERIMENTAL PLOTS OF PRAWN WITH MOLA FISH IN THE RICE FIELDS.

Parameters	T_1	T_2	T_3	T_4
Temperature (^{0}C)	30.08 ± 0.12^a	29.82 ± 0.03^a	30.62 ± 0.03^a	30.57 ± 0.08^a
DO (mg/l)	4.83 ± 0.04 ^{a}	5.33 ± 0.04^a	5.41 ± 0.02^a	5.25 ± 0.05^a
pH	7.72 ± 0.08^a	7.80 ± 0.03^a	7.84 ± 0.03^a	7.72 ± 0.07^a
Chlorophyll-a (µg/l)	113.37 ± 1.54^a	118.65±1.74^a	103.35 ±2.81^a	90.06 ±2.56^a
Alkalinity (mg/l)	13.88 ±0.38^a	65.38 ±56.18^a	58.62 ±5.66^a	61.28 ± 1.79^a
NH_3 (mg/l)	0.24 ± 0.003^a	0.25± 0.003^a	0.27 ±0 .006^a	0.19 ± 0.01^a
PO_4 (mg/l)	0.22 ± 0.005^a	0.33 ± 0.003^a	0.26 ± 0.007^a	0.16± 0.003^a
NO_3 -N(mg/l)	0.40 ± 0.008^a	0.37 ± 0.003^a	0.36 ± 0.008^a	0.21 ± 0.004^a

Mean values with the same superscripts in the same row are not significantly different ($P > 0.05$).

B. Growth and production of fish

The growth, survival and production performances of fish under different treatments are summarized in the Table 2. Although there was no significant ($P < 0.05$) differences in initial weight of fish among the treatments, at the end of the experiment the mean final weight of prawn was significantly higher ($P < 0.05$) in T_2 than those in T_3 and T_4, while the values between T_1 and T_2 were very similar. The mean final weight of mola was slightly higher in T_3 followed by T_1, T_2 and T_4, but variation among the treatments were not significant ($P > 0.05$).

Among the treatments evaluated, the highest production of prawn (386.20 kg/ha) and mola (70.68 kg/ha) were obtained in the plots of T_2 where stocking densities of prawn and mola were 15,000/ha and 20,000/ha, respectively. Kurup and Ranjeet [17] did integration of prawn with fish in rice-fish farming and found 70-500 kg/ha of prawn. The present production level of prawn was more or less similar with the above reported prawn production. On the other hand, the production of mola (25.9-29.2 kg/ha) recorded by Das [13] in combination with other fish species was lower than the production obtained in the present study. The higher production in the present study was possibly due to the better environmental conditions prevailed in the experimental plots.

The mean survival of prawn was ranged from 39.58 to 49.65% in different treatments. Significantly higher ($P < 0.05$) survival rate was found in T_2 than those in T_1, T_3 and T_4 respectively. Haroon et al. [18] recorded the survival rates of 70.74 to 80.41% in prawn which was higher than the survival rate obtained in the present study; whereas, Haroon and Alam [19] recorded the survival rate ranged from 53.90 to 70.24%, which was also higher than those recorded in the present study. The lower survival of prawn in the present study might be due to the smaller size of fingerlings at stocking. However, the survival rate of *A. mola* was not recorded because it had spawned after stocking; therefore harvesting number was too much high than stocking.

The mean specific growth rate (SGR) of prawn was ranged from 2.78 to 3.16% in different treatments. Significantly higher ($P < 0.05$) SGR of prawn was found in T_2 than those in T_1, T_3 and T_4 in that order (Table 2). Parvez et al. [14] recorded the SGR of 2.312.25% in only prawn culture, which were lower than those of obtained in the present study.

TABLE 2. MEAN ± SE VALUES OF GROWTH, SURVIVAL AND PRODUCTION OF PRAWN AND MOLA UNDER DIFFERENT RICE-FISH TREATMENTS.

Parameters	Species	Treatment			
		T1	T2	T3	T4
Mean Initial Weight (g)	Prawn	1.154±0.008^a	1.25±0.005^a	1.20±0.008^a	1.17±0.007^a
	Mola	1.16±0.008^a	1.21±0.013^a	1.32±0.015^a	1.31±0.017^a
Mean final weight (g)	Prawn	53.18±1.90^a	55.34±2.57^a	44.12±1.87^b	33.95±2.40^c
	Mola	3.15±0.012^a	3.16±0.003^a	3.49±0.030^a	3.36±0.06^a
Survival (%)	Prawn	44.25±0.95^b	49.65±1.47^a	39.58±0.43^c	43.55±3.27^a
	Mola	ND	ND	ND	ND
Specific Growth Rate SGR (%/day)	Prawn	3.16±0.023^a	3.10±0.011^a	2.93±0.440^{ab}	2.77±0.060^b
	Mola	ND	ND	ND	ND
Production (Kg/ha)	Prawn	238.16±5.41^a	386.20±4.96^a	322.65±2.95^a	334.23±1.72^a
	Mola	58.29±1.65^b	70.68±1.23^a	61.97±1.79^b	51.02±11.36^a
Total production (Kg/ha)		296.45^c	456.88^a	384.62^b	385.25^b

ND = Not determined (mola had bred after stocking, therefore harvesting number was too much high than stocking). Mean values with the same superscripts are not significantly different ($P > 0.05$).

C. Yields of rice and straw

The highest yield of grain (3.86 mt/ha) and lowest production of straw (3.39 mt/ha) were obtained in T_2 and the lowest production of grain (3.02 mt/ha) and highest production of straw (4.15±0.03 mt/ha) were recorded in T_4. There was no significant differences ($P > 0.05$) recognized in the yield of rice among the treatments. The yields of straw were also followed the more or less similar trends as rice production (Table 3). The yields of rice grain and straw obtained in the present study were more or less similar to the yields of the same recorded by Das [13]. But the yield of rice grain and straw recorded by Uddin [11], Mondal [12], and Chowdhury [20] were less than the yields of the same obtained in the present study. However, the yield of grain found in other rice-fish experiments [19, 21, 22, 23] were more or less close to that obtained in the present study.

D. Cost and benefit

A simple economic analysis was performed to estimate the net benefits from the integrated culture operation (Table 4). The highest gross (BDT 479,087/ha) and net (BDT 309,487/ha) benefits were obtained in T_2, where the stocking densities of prawn and mola were 15,000 and 20,000 individual/ha respectively. Khan et al. [24] found the highest benefits from the integration of rice with fish at the same stocking densities. In the present study, benefit-cost ratios (BCR) of 2.59, 2.83, 1.69 and 1.36 were obtained in T_1, T_2, T_3 and T_4, respectively, which are more or less similar to the values obtained by Ali [25] from the integration of rice with fish farming. Similar BCR values were also obtained by Chowdhury [20] from the culture of *A. mola* and *B. gonionotus* with rice farming.

TABLE 3. MEAN (±SD) YIELDS OF RICE GRAIN AND STRAW IN DIFFERENT INTEGRATED RICE-FISH TREATMENTS.

Treatment	**Mean yield (mt/ha)**	
	Rice	**Straw**
T_1	3.78±0.04[a]	4.30±0.03[a]
T_2	3.88±0.05[a]	3.39±0.03[a]
T_3	3.31±0.04[a]	3.93±0.02[a]
T_4	3.02±0.04[a]	4.15±0.03[a]

Mean values with the same superscripts are not significantly different ($P > 0.05$).

TABLE 4. COMPARISON OF COST AND BENEFITS OBTAINED FROM DIFFERENT RICE-PRAWN-MOLA CULTURE SYSTEMS.

Items	**Costing**			
	T1	**T2**	**T3**	**T4**
Cost				
Tilling	2,800	2,800	2,800	2,800
Construction of ditch	2,800	2,800	2,800	2,800
Seedling	2,800	2,800	2,800	2,800
Urea	1,500	1,500	1,500	1,500
TSP	2,500	2,500	2,500	2,500
MP	800	800	800	800
Feed	9,000	14,000	21,000	32,000
Mola	5,000	5,000	5,000	5,000
Prawn	100,000	150,000	200,000	250000
Total cost	127,200	182,200	239,200	300,200
B. Benefits:				
Rice	75,600	77,200	66,200	60,400
Straw	6,450	5,085	5,895	6,225
Prawn	238,160	386,200	322,650	334,230
Mola	8,743.5	10,602	9,295.5	7,653
Gross benefits	328,953.5	479,087	404,040.5	408,508
Net benefit	201,753.5	309,487	164,840.5	108,308
(B-A)				
Benefit-cost ratio	2.59	2.83	1.69	1.36

IV. Conclusion

Based on the result of the study, it can be concluded that the growth, survival, production and benefits of prawn and mola at stocking densities of 15,000/ha and 20,000/ha, respectively showed highest performances than those obtained in other stocking densities. Therefore, these stocking densities of prawn and mola may be advisable for integrated rice–fish farming in Bangladesh.

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