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Species suitability for fish farming in irrigated rice fields of drought prone Barind area of Bangladesh

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Abstract
Species Suitability for fish farming in irrigated rice-fish culture system of drought prone barind area were evaluated on the basis of production performance and cost analysis for a period of 4 months. Three most commonly used fish species were tested under three treatments (T_1: Nile tilapia- *Oreochromis niloticus*; T_2: Thai Sarpunti- *Barbodes gonionotus* and T_3: carpio- *Cyprinus carpio*) in rice-fish culture system of drought prone Barind area to find out suitable fish species. The fish fingerlings stocking density (4940 ha^{-1}) of three species and management practices were similar in all plots. The water quality parameters, such as temperature, transparency, pH, dissolved oxygen, ammonia nitrogen and alkalinity were studied. Soil organic matter, available nitrogen and phosphorous were increased significantly ($P < 0.05$) in all plots after cultivating the fish. Specific growth rate, survival and fish production were significantly ($P < 0.05$) varied among the treatments. However, significantly ($P < 0.05$) higher net income and benefit–cost ratio were obtained in treatment T_1 with the values of 34296.24 Tk ha^{-1} and 1.55 higher than the treatment T_2 and treatment T_3 respectively. Present findings indicate that the hardy fish like tilapia performed better in terms of production and economics than that of others fish species (Thai sarpunti and common carp) in rice-fish system in Barind area. So, it can be recommended that tilapia can be a good option while selecting aquaculture species for rice field in this red soil zone of Bangladesh.

Keywords: species suitability, irrigated rice-fish culture, red soil zone

1. Introduction
A wide range of fish species are used in rice-fish farming in the world. The most commonly used species are common carp (*Cyprinus carpio*), Nile tilapia (*Oreochromis niloticus*), and silver barb (*Barbonymus gonionotus*) [13, 15, 25]. In China, predominant species, apart from the common carp, are crucian carp (*Carassius carassius*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Arsitichthys nobilis*), and grass carp (*Ctenopharyngodon idella*) [9, 12]. In India, native carp species, i.e., *Catla catla*, *Cirrhinus mrigala* and *Labeo rohita*, are commonly stocked in rice fields. Seasonal ponds, canals and rice fields under drought prone Barind area are more suitable for monoculture of fishes than that of polyculture. Compared to polyculture, monoculture does not require great deal of attention and can be carried out at small scale also. Monoculture involves culture of only single species of organisms and so separation of fish into different age, sex and size is much easier than polyculture. Monoculture of consumer preferred species has been practiced in many countries and has resulted in high survival rate and production [32].
Nile tilapia (*Oreochromis nilotica*), Thai sarpunti (*Barbodes gonionotus*) and common carp (*Cyprinus carpio*) are considered important aquaculture species for rice-fish culture system in Bangladesh. The selectivity criteria of species should be considered by quality of the species itself, its growing nature, feeding habit, soil condition and water depth of ditch and quality of specific rice plot. Though rice fish farming is an ancient practice in Asia [27] but details study to investigate its feasibility and comparative productivity is still in its initial stage. Region specific research efforts are not taken accordingly in promoting the rice-fish system in Bangladesh. Characteristics soil (low organic matter content) and water (high clay turbidity and low alkalinity) are creating complexities in land and water based farming and thereby making the livelihood critical of the farmers of drought prone Barind area of Bangladesh. To minimize the fish production cost of the irrigation depended farmers and to explore the benefits of rice-fish system especially in drought prone Barind area, it is necessary to conduct

research on fish farming in irrigated rice field of this zone. Therefore, the present study was aimed to find out suitable fish species for farming in irrigated rice field of drought prone Barind ecosystem.

2. Materials and methods

2.1 Duration and location of the study

The experiment was carried out for a period of four months (March 2009 to June 2009) in irrigated rice fields at Bijoynagar of Godagari Upazila under Rajshahi district, Bangladesh. The study site belonged to a typical drought prone Barind area.

2.2 Experimental Design

The experiment was conducted in a randomized complete block design (RCBD) with three treatments and three replications for each treatment. The treatments were: (T_1) rice combined with 4940 individuals/ha of tilapia (*Oreochromis niloticus*), (T_2) rice combined with 4940 individuals/ha of Thai sarpunti (*Barbodes gonionotus*) and (T_3) rice combined with 4940 individuals/ha of carpio (*Cyprinus carpio*).

2.3 Field Management

Experimental rice plots (mean area of 0.14 ha) were more or less similar in size. The fields were ploughed with the help of a power tiller and then leveled properly by laddering to keep equal water depth throughout the field. Dyke around the land was constructed at the height of 25 cm. A small ditch (1.5 m × 1.5 m × 1 m) was constructed at the lower part of the field to provide refuge during high water temperature and low water depth. All the experimental plots were prepared well and fertilized with urea, triple super phosphate (TSP) and murate of potash (MP) at the rate of 200 kg/ha, 150 kg/ha and 75 kg/ha, respectively as recommended by BRRI (1999). The present experiment was conducted during Boro season. High yielding variety (HYV) rice BR-28 was selected for this experiment. Alternate row spacing of 35 cm and 15 cm was followed for transplanting rice seedling following Hossain *et al.* [21]. The plant to plant distance was 20 cm. The alternate row spacing would provide enough space for easy movement of fish and allow adequate sunlight to ensure enough biological production.

2.4 Stocking and management of fish

Fifteen days after transplantation of rice seedlings, fields under different treatments were stocked with fish fingerlings. All the treatments of rice-fish system belonged to a similar stocking density of 4940 fish ha^{-1}. The mean initial weight of tilapia, sharpunti and carpio were 20.30, 20.35 and 20.80 g, respectively. Fishes were grown for a period of 120 days in the plots and rice was harvested just after harvesting the fishes.

2.5 Chemical analysis of soil

To determine the nutrient concentration of soil, the soil samples were collected at a depth of 0-15 cm from the surface of each treatment. The samples were collected in two installments: first before rice transplantation and finally, after the harvest of rice and fish then the samples were air dried and ground to pass through 2 mm sieve. Then the parameters of soil viz., pH, organic matter and total nitrogen were analyzed by following standards methods outlined by Jackson [23], Black [5] and Page [30].

2.6 Water quality parameters

During the study period, the status of physicochemical parameters of water like temperature, transparency, dissolved oxygen, pH, alkalinity, ammonia, nitrate-nitrogen, phosphate-phosphorus were recorded fortnightly. Water temperature, transparency, dissolved oxygen and water pH were recorded directly in the field with the help of a Celsius thermometer, secchi disc, a digital electronic DO meter (YSI, Model 58) and an electrical pH meter (JENWAY, Model 3020). The concentration of ammonia-nitrogen (mg L^{-1}), total alkalinity (mg L^{-1}) and free carbon dioxide (mg L^{-1}) of water samples were determined by using a HACH kit (FF-2, USA). The plankton were identified up to genus level and enumerated by the following [3, 33].

2.7 Fish Growth Analysis

Following parameters were used to determine production of fishes under different treatments.

Weight gain (g) = Final weight (g) – Initial weight (g)

$$\text{Specific growth rate (\%/day)} = \frac{ln\ \text{Final weight (g)} - ln\ \text{Initial weight (g)}}{\text{Study period}} \times 100$$

$$\text{Survival rate (\%)} = \frac{\text{Final fish number}}{\text{Initial fish number}} \times 100$$

Fish yield ($kgha^{-1}\ 4^{-1}$ month) = Fish biomass at harvest – Fish biomass at stock

2.8 Economic analysis

At the end of the experiment, rice and fish were sold locally and the total return was estimated. The following parameters were used to explore the economics of different treatments of rice-fish system:

Net benefit (Tk.) = total return (sale) – total cost (investment)

$$\text{Net profit margin (\%)} = \frac{\text{Net benefit}}{\text{Total investment}} \times 100$$

$$\text{CBR} = \frac{\text{Net benefit}}{\text{Total investment}}$$

2.9 Statistical Analysis

Data related on water and soil quality parameters, rice and fish production, and economics under different treatments were subjected to one way ANOVA (Analysis of Variance) using computer software SPSS (Statistical Package for Social Science, version-20). The mean values were also compared to see the significant difference from the Duncan Multiple Range Test [11].

3. Results and Discussion

3.1 Water Quality Parameters

The range of mean water temperature recorded in the present study was found to vary from 33.29-33.42 °C in all the treatments (Table 1). The findings of the present study is quite similar to the findings recorded by Hossain *et al.* [20] in the irrigated rice fields of Barind area of Rajshahi, Bangladesh where water temperature was ranged between 35.03-35.84 °C. In the present study, the mean value of water transparency varied from 15.71±2.51 to 16.92±2.74 cm. The lower transparency throughout the study period might be due to the higher clay turbidity in the red soil zone, it was not directly related to plankton concentration [17]. The mean value of pH varied from 6.42±0.14 to 6.63±0.04. Rasowo and Auma [31] and Hossain *et al.* [20] recorded pH in rice-fish culture system as 6.3-6.85 and 6.34-6.81, respectively which were quite similar to the present study. The range of dissolved oxygen content of the present study (3.14±0.07 to 3.56±0.11) were found to lie within the values 3.90-4.50 mg L^{-1} and 2.92-3.54 mg L^{-1} recorded by Chowdhury *et al.* [8] and Hossain *et al.* [20] respectively in their study on rice-fish culture system. Dissolved oxygen (DO) content was relatively low in treatment T_3 than T_1 and T_2. This might be due to activity of *C. carpio* in the bottom of rice fields which make the water turbid and lowers DO content. The mean value of free carbon dioxide varied from 11.18±0.51 to 12.15±0.33 mg L^{-1}. Arunava *et. al.* [1] reported the CO_2 value as 4.95 to 9.2 mg L^{-1} in fish culture pond. The present finding is quite higher which might be due to high temperature and low photosynthetic activity due to high turbidity and this statement was strongly agreed with Boyd [7]. In the present study, ammonia-nitrogen value ranged from 0.22±0.01 to 0.25±0.02 mg L^{-1}, which strongly agreed with the findings of Hossain *et al.* [20] who found that the mean value of NH_3-N was 0.30-0.34 mg L^{-1} in rice fish culture system. The mean value of total alkalinity varied from 11.00±0.63 to 11.55±0.65 mg L^{-1}. It is desirable to have an alkalinity of above 20 mg L^{-1} for optimal fish production [2, 6]. Comparatively lower alkalinity level with the rice-fish plots, might be due to the special characteristics of soil-water quality (high clay turbidity, slightly acidic pH and lower alkalinity) under the red soil zones. And this statement strongly agreed with Hossain and Bhuiyan [17] and Hossain and Bhuiyan [18] who made similar assumptions while working on untreated fertilized fish ponds in Barind area.

Table 1: Variations in the mean values of physico-chemical parameters under different treatments of rice-fish system.

	Treatments				
Variables	**T_1**	**T_2**	**T_3**	***F*-value**	***P*-value**
Water temperature (°C)	33.34±1.17^a	33.29±1.10^a	33.42±1.17^a	0.003	0.997
Transparency (cm)	15.71±2.51^a	16.38±2.75^a	16.92±2.74^a	0.052	0.950
pH	6.63±0.04^a	6.42±0.14^a	6.49±0.20^a	0.526	0.608
DO (mg/l)	3.56±0.11^a	3.49±0.18^a	3.14±0.07^a	3.049	0.097
CO_2 (mg/l)	12.15±0.33^a	11.66±0.54^a	11.18±0.51^a	1.076	0.381
NH_3-N (mg/l)	0.22±0.01^a	0.24±0.03^a	0.25±0.02^a	1.973	0.195
Alkalinity (mg/l)	11.55±0.65^a	11.00±0.63^a	11.33±0.93^a	0.136	0.875

Figures in a row bearing common letter(s) do not differ significantly (p<0.05)

3.2 Soil quality parameters

Availability of nutrients in soil of different treatments were determined before fish stocking (initial) and after harvest of rice and fish (final) to know the variations in the availability of nutrients in soil of rice fields among different treatments. No significant difference was observed in the before rice-fish culture of organic matter, total nitrogen and pH among the three treatments, but the final values (after rice-fish culture) of the same showed significant ($p<0.05$) differences among the treatments (Table 2). The significantly higher concentrations of nutrients in the soil (after harvesting rice and fish) of all treatments clearly indicate that the introduction of fish in the rice fields improved the nutritional status of soil. This might be associated with the accumulation of fish faeces and stirring and turbulence action of fish in rice fields. Present findings are in conformity with the findings of Middendrop [28] and Gaunt *et al.* [10] who stated that the activities of microorganisms and release of nutrients are stimulated by the introduction of fish in the rice fields stimulates.

Table 2: Comparison of soil quality parameters before and after rice–fish culture

Variables	Treatments	Before rice-fish culture	After rice-fish culture	Change (%)	t-value	P-value
pH	T_1	6.0±0.06^a	6.50±0.06^a	8.33	- 2.682	0.115
	T_2	5.90±0.06^a	6.33±0.03^b	7.29	- 6.928*	0.020
	T_3	5.95±0.06^a	6.40±0.03^{ab}	8.40	- 26.000***	0.001
Organic matter (%)	T_1	0.75±0.01^a	0.94±0.06^a	25.33	- 59.000***	0.000
	T_2	0.76±0.01^a	0.90±0.03^b	18.42	- 8.083*	0.015
	T_3	0.77±0.01^a	0.92±0.06^b	19.48	- 17.386**	0.003
Total nitrogen (%)	T_1	0.05±0.01^a	0.07±0.003^a	24.00	- 5.000*	0.038
	T_2	0.06±0.01^a	0.07±0.01^b	16.67	- 0.500	0.667
	T_3	0.07±0.01^a	0.08±0.01^b	14.29	- 0.459	0.691

***P < 0.001, **P < 0.01, *P < 0.05; mean SD.

3.3 Rice and straw production

Variations in mean values of rice yield under different treatments are shown in table 3. Rice production varied from 3.82±0.02 to 4.03±0.03 ton ha^{-1} during the study period. The minimum production was recorded in treatment T_2 whereas the maximum production was recorded in treatment T_1. Hossain *et al.* [20] and Hossain and Joadder [19] recorded the production of rice yield in rice-fish culture system as 3.43 to 4.03 and 3.47 to 3.49 ton ha^{-1} in 4 months culture period which was almost similar to the present study. Straw production varied from 3.85±0.10 to 4.40±0.43 ton ha^{-1}. Statistically significant differences ($P<0.05$) were found in the yield of straw under different treatments.

Table 3: Variations in mean values of rice and straw production under different treatments of rice-fish system.

	Treatments				
Variables	**T_1**	**T_2**	**T_3**	***F*-value**	***P*-value**
Rice grain (ton/ha/4months)	4.03 ± 0.03^a	3.82 ± 0.02^a	3.95 ± 0.03^a	4.462	0.065
Straw (ton/ha/4months)	4.40 ± 0.43^a	3.85 ± 0.10^c	4.10 ± 0.18^{ab}	19.500	0.002

Each value is expressed as mean ± SD (n = 3). Mean values followed by different superscript letters in each row indicate significant differences (P < 0.05) based on DMRT.

3.4 Fish growth rate and production performance

The variations in the mean values of fish growth parameters in terms of final weight, weight gain, SGR, survival rate and yield under different treatments are shown in table 4. In the present study, the highest mean weight gain (22.38±1.64 g) was obtained in T_1 (Tilapia monoculture) and lowest weight gain (16.42±1.00 g) was found in T_2 (Thai sarpunti monoculture). The differences in weight gain under three treatments were highly significant ($P\leq0.05$). The mean specific growth rate (%, bwd^{-1}) of fishes varied from 1.21±0.20 (T_2) to 1.43±0.30 (T_1). The highest mean specific growth rate was found in the treatment T_1 for Tilapia monoculture and the lowest mean specific growth rate was found in the treatment T_2 for Thai sarpunti monoculture. Comparatively higher mean specific growth rate of tilapia in treatment T_1 might be due to the capability of higher metabolic activity and fast growing characteristics of tilapia which agreed with the findings of Hussain [22]. In the present study, lower (1.21) SGR was recorded with the treatment T_2 (Thai sarpunti), which was more or closer to the findings of Kohinoor *et al.* [24] who observed the SGR value of Thai sharpunti as 1.33 to 1.35%, bwd^{-1} in fish pond. The mean final weight of fishes at harvest was found to be ranged from 85.00±0.76 g to 109.83±1.01 g. The maximum value (109.83 g) was recorded in treatment T_1 whereas minimum was recorded in treatment T_2. The higher final weight in treatment T_1 might be due to higher growth rate of Tilapia in extremely adverse environment than Thai sarpunti (T_2) and *C. carpio* (T_3). This statement is strongly supported by Liu and Chang [26] who reported that Tilapia has high growth rate and this species can survive in extremely adverse condition. Fish yield varied significantly under the different treatments of rice-fish farming system. The mean yield (kg/ha/4 months) of fishes varied from 208.72±9.27 (T_2) to 377.91±12.83 (T_1). In the present study, higher fish yield was found in the treatment T_1 (377.91 kg/ha/4 months) for Tilapia monoculture which might be due to higher adaptability in abnormal environmental condition, higher survaibality, high metabolic activity and fast growing characteristics of Tilapia, almost similar assumption was made by Liu and Chang [26]. Bangladesh Fisheries Research Institute (BFRI) [4] reported that about 325-350 kg/ha of fish can be produced along with rice per ha of land within 3-4 months in polyculture system which was more or less close to the present study. Hossain and Joadder [19] found yield of tilapia as 613.80 kg/ha/4 months in rice-fish culture system, which is higher than the present study, it might be due to the differences in location and environment of experimental sites in both cases.

Table 4: Variations in mean values of fish production parameters under different treatments of rice-fish system.

	Treatments				
Variables	**T_1**	**T_2**	**T_3**	***F*-value**	***P*-value**
Initial weight (g)	20.30 ± 0.12^a	20.35 ± 0.09^a	20.80 ± 0.17^a	32.630	0.612
Weight gain (g/month)	22.38 ± 1.64^a	16.42 ± 1.00^b	21.05 ± 1.79^{ab}	4.254	0.050
SGR (%, bwd^{-1})	1.41 ± 0.28^a	1.23 ± 0.23^b	1.35 ± 0.24^a	0.126	0.883
Survival rate (%)	85.00 ± 2.89^a	65.00 ± 2.89^b	70.00 ± 2.89^b	13.000	0.007
Final weight (g)	109.83 ± 1.01^a	85.00 ± 0.76^c	105.00 ± 0.87^b	220.247	0.000
Gross yield	460.90 ± 11.42^a	272.73 ± 9.86^c	363.34 ± 17.97^b	48.263	0.000
Net Yield (Kg/ha/4 months)	377.91 ± 12.83^a	208.72 ± 9.27^c	293.93 ± 12.12^b	54.003	0.000

Each value is expressed as mean ± SD (n = 3). Mean values followed by different superscript letters in each row indicate significant differences (P < 0.05) based on DMRT.

3.5 Cost Analysis

The cost analysis of different treatments of rice-fish system are shown in table 5. The major variable input costs were mainly due to fertilizer, seed, labor and irrigation. The total cost was estimated lowest (43170.00 Tk ha^{-1}) in treatment T_2 and the highest (44060.00 Tk ha^{-1}) was found in treatment T_1. In the present study, net return varied significantly among the three treatments. The highest net return (34296.24 Tk ha^{-1}) was found in treatment T_1 whereas the lowest (15371.34 Tk ha^{-1}) was obtained in treatment T_1 (Table 5).

In the present study, higher net benefit, profit margin and BCR were found in treatment T_1 (Tilapia monoculture) and lowest net benefit, profit margin and BCR were recorded in treatment T_2 (Thai sarpunti monoculture). The economics in the present study clearly indicates that, tilapia culture in rice fields under drought prone Barind tract is more profitable than other fish species. These statements were strongly supported by Hora and Pillay [16] and Mohanty *et al.* [29] who reported that the cultivation of tilapia in rice fields increases rice yields over rice monoculture. Similar observation was also found by Halwart and Gupta [14] who reported that tilapia feed low in the food chain and are therefore preferred species in the culture systems. Treatment T_1 was found to vary more significantly than that of other treatments for the value of profit margin indicating that tilapia farming in rice fields under drought prone Barind area is more profitable than others fish species. Almost similar potentials for tilapia farming were also reported by Hossain *et al.* [20] and Hossain and Joadder [19] in rice-fish system in Bangladesh.

Table 5: Comparison of cost analysis parameters among the treatments of rice–fish culture system. Calculation was for 1 ha rice field and 120 days of experimental duration.

		Treatments (mean value in Tk.)				
Variables	**Amount**	**T_1**	**T_2**	**T_3**	***F*-value**	***P*-value**
Variable cost						
Rice seeds	kg	1250.00±0.00^{a}	1250.00±0.00^{a}	1250.00±0.00^{a}	-	-
Fertilizer	kg	12500.00±0.00^{a}	12500.00±0.00^{a}	12500.00±0.00^{a}	-	-
Labour	Man-day	9000.00±0.00^{a}	9000.00±0.00^{a}	9000.00±0.00^{a}	-	-
Fish fingerlings	pcs	6460.00±58.32^{a}	6310.67±57.17^{a}	6290.67±46.31^{a}	2.914	0.131
Rice field preparation cost	1 ha	3250.00±0.00^{a}	3250.00±0.00^{a}	3250.00±0.00^{a}	-	-
Irrigation cost		9500.00±0.00^{a}	9500.00±0.00^{a}	9500.00±0.00^{a}	-	-
Ditch management cost		550.00±0.00^{a}	550.00±0.00^{a}	550.00±0.00^{a}	-	-
Post management cost		860.00±0.00^{a}	860.00±0.00^{a}	860.00±0.00^{a}	-	-
Total variable cost		43170.00±5.20^{a}	44060.00±1.73^{a}	43410.00±1.15^{a}	20105.06	0.210
Fixed cost						
Land used cost		15000.00±0.00^{a}	15000.00±0.00^{a}	15000.00±0.00^{a}	-	-
Total		58170.00±5.12^{c}	59060.00±1.48^{a}	58410.00±1.26^{b}	20301.06	0.215
Interest (4 months)		1905.66±0.00^{a}	1905.66±0.00^{a}	1905.66±0.00^{a}	-	-
Total inputs		60075.66±4.25^{a}	60965.66±1.23^{a}	60315.66±0.59^{a}	20351.06	0.351
Financial returns						
Rice		48360.00±1.15^{a}	45840.00±1.73^{c}	47400.00±1.15^{b}	856376.47	0.000
Rice straw		11000.00±2.89^{a}	9625.00±1.73^{c}	10250.00±1.15^{b}	112253.29	0.000
Fish		34011.90±0.58^{a}	20872.00±1.15^{c}	23514.40±1.54^{b}	48306126.00	0.000
Gross return		93371.90±0.49^{a}	76337.00±1.24^{c}	81164.40±0.84^{b}	115628666.26	0.000
Net return		34296.24±2.51^{a}	15371.34±1.02^{c}	20848.74±1.47^{b}	71123625.88	0.000
Benefit-cost ratio (BCR)		1.55±0.05^{a}	1.25±0.01^{c}	1.35±0.06^{b}	377.71	0.000

Mean values in the same row with no superscript letter in common differ significantly ($P < 0.05$). Currencies are given in Bangladesh Taka, BDT (1 US$ = 80 BDT). 10% interest according to Rajshahi Krishi Bank.

4. Conclusion

In the present study, all the growth parameters were higher in treatment T_1 (Tilapia monoculture) and net benefit and profit margin were also higher in treatment T_1 than the other treatments of rice-fish culture system. Study indicates that tilapia can be a good option while selecting aquaculture species for rice field in this red soil zone (Barind area). Present findings indicate that the hardy fish like tilapia performed better in terms of production and economics than that of others fish species (Thai sarpunti and common carp) in rice-fish system in Barind area.

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