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Research Article

Productivity and Economics of Rice-fish Culture under Different Plant Nutrient Management

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Abstract

Background and Objective: The productivity of rice-fish culture mostly depends on the nutrient management and proper fish species selection. A study was conducted to evaluate the effect of plant nutrient management on the productivity of rice-fish culture. **Materials and Methods:** High yielding Boro rice variety BRRI dhan 29 was used in this study. Factors included 6 different plant nutrient management viz. (1) No fertilizer/manure, (2) Recommended fertilizer (RF) for rice, (3) 75% RF, (4) Compost at the rate of 10 t ha^{-1} and (5) Compost at the rate of 5 t ha^{-1}+75% RF, (vi) Compost at the rate of 5 t ha^{-1}+50% RF and 3 fish species such as (1) No fish, (2) Tilapia and (3) Common carp. **Results:** Rice plant growth was significantly affected by nutrient management but not by fish species. All the yield parameters were influenced by nutrient management but only grains/panicle was influenced by fish species. Recommended fertilizer resulted in the highest grain weight/hill. Integration of fish with rice resulted in higher grain weight/hill of rice compared to rice sole culture. Rice sole culture and rice-fish culture produced similar grain yield. Tilapia yielded the highest with 75% RF+compost at the rate of 5 t ha^{-1} (545 kg ha^{-1}) or with 100% RF (514 kg ha^{-1}). While for common carp, application of compost at the rate of 5 t ha^{-1}+50% RF yielded the highest (625 kg ha^{-1}). **Conclusion:** Rice-fish culture was found more remunerative than rice sole culture in terms of net return and benefit cost ratio. Therefore, considering the productivity and profitability, either tilapia or common carp can be integrated with rice following recommended fertilizer application.

Key words: Integrated rice fish farming, tilapia, carp, rice nutrient management, fish yield, rice productivity, economic performance

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice-fish farming, an integrated rice field or rice field/pond complex, where fish are grown concurrently or alternately with rice, offers a solution to this problem by contributing to food, income and nutrition. Rice-fish farming supplies both carbohydrate and animal protein to human diet. Human nutrition can be greatly improved through consumption of particularly small fishes which are rich in micronutrients and vitamins. Bangladesh has 10.1 million ha of rice field with further 2.8 million ha low land rice field which remain inundated for 4-6 months[1]. These potential low lands are underutilized and could be explored for increasing freshwater fish production. Integrated rice-fish farming is a unique system that not only offers intensification and diversification but also increase the system productivity and profitability in a sustainable way[2-4]. But rice-fish integrated farming is still at the marginal stage in Bangladesh due to lack of appropriate technologies and some socioeconomic constraints. Despite few successful demonstration and farmers training program on rice-fish farming, this integrated approach is not widely practiced till now in Bangladesh. It is well documented that rice-fish integration improves soil fertility through increasing N and P availability and thus this ecologically a sound system[5-6]. Fish increases aeration in rice field while scavenging for foods, helps control aquatic weeds, algae, flies, snails and insects and thus rice-fish farming is considered as an important component of integrated pest management (IPM) in rice[7]. Through controlling insect pests and diseases, integration of fish with rice lowers rice production cost. Rice fields, on the other hand provide planktonic, epiphytic and benthic food for fish[8] and also maintain favorable water temperature for fish through shading by rice plants during hot days[9].

Fertilization is a complex issue and varies greatly depending on the particular location. It is evident from previous studies that nutrient utilization in rice-fish systems is more efficient than rice sole culture, especially on soil with poor fertility or unfertilized soils[10]. Rice-fish systems are often associated with recycling of nutrients, improvements in resource utilization and increase in soil fertility due to accumulation of nitrogen[2,11]. Application of fertilizers, organic or inorganic, benefits both rice and fish. The presence of adequate nutrients increases the growth of phytoplankton, which may be consumed directly by the fish or indirectly through supporting zooplankton production. Early speculations indicated that rice-fish farming might use from 50-100% more fertilizers than rice farming without fish[12] where the additional fertilizer was deemed necessary to support phytoplankton production as the base of the fish culture food chain.

Recent reports indicate that the presence of fish in the rice field may actually boost rice field fertility and lower fertilizer needs. Experiments in China indicate that the organic nitrogen, alkaline nitrogen and total nitrogen in the soil are consistently higher in fields with fish than in the control fields without fish[13]. Sustainable aquaculture depends upon eco-friendly, economically and socially viable culture systems. The recycling of organic waste in fish ponds for fish production is important to sustainable aquaculture, as well as to reduce expenditures on costly feeds and fertilizers which form more than 50% of the total cost input. However, rather than improving pond productivity, indiscriminate use of these manures in fish ponds may also lead to pollution[14]. Fertilizer application as one of the management strategies in the rice-fish field is carried out principally to promote growth and production of both rice and fish. However, indiscriminate fertilizer treatments might positively or negatively affect the ecosystem quality to the benefit or detriment of live aquatic organisms, including fish, either artificially introduced or naturally existing in the environment[15]. The experiment was therefore conducted to study the comparative productivity and profitability of common carp and tilapia in rice-fish farming under different nutrient management.

MATERIALS AND METHODS

Experimental site: The experiment was conducted at the Agronomy field laboratory of Bangladesh Agricultural University, Mymensingh located at 24°75'N latitude and 90°50'E longitude and at an altitude of 18 m above the sea level during the period from December, 2017 to May, 2018 in the Boro season. The experimental area belongs to the non-calcareous dark grey soil under Agro-ecological Zone of the Old Brahmaputra Floodplain (AEZ-9). The land was medium high and well drained with silty-loam texture. The soil of the experimental field was more or less neutral in reaction (pH: 6.64) organic matter content (1.23%), total nitrogen (0.11%), available phosphorous (26.05 ppm), exchangeable potassium (0.16 me %) and the general fertility level of the soil was low. The general climate of the locality is sub-tropical in nature and is characterized by high temperature and heavy rainfall during Kharif season (April to September) and scanty of rainfall associated with moderately low temperature during

Table 1: A brief description of the crop variety and fish species used in this experiment

Materials	Cultivar/species	Key features
Rice	BRRI dhan 29 (*Oryza sativa*)	BRRI dhan 29 is the most popular high yielding boro (winter) rice variety developed by the Bangladesh Rice Research Institute, the plant is 80-100 cm in height, It matures within 140-160 days with yield of 5-6 t ha^{-1}, the grains are medium bold with white kernels, It is resistant to blight, stem rot, tungro and blast diseases
Fish	Nile tilapia (*Oreochromis nilotcus*)	Tilapias are saprophyte-feeders, feeding on a diverse range of filamentous algae and plankton, adults reach up to 60 cm in length and up to 4.3 kg, It lives for up to 9 years, It tolerates brackish water and survives temperatures between 8 and 42°C, Nile tilapia reproduces through mass spawning of a brood within a nest
	Common carp (*Cyprinus carpio*)	Common carp prefers large bodies of slow or standing water and soft, vegetative sediments, naturally live in temperate climates in fresh or slightly brackish water with a pH of 6.5-9.0 and temperatures of 3-35°C, common carp are omnivorous, they can eat an herbivorous diet of aquatic plants, but prefer to scavenge the bottom for insects, crustaceans (including zooplankton), crawfish and benthic worms, typical adult female can lay 300,000 eggs in a single spawn

Rabi season (October to March). The average air temperature, rainfall (monthly total), relative humidity (monthly average) and sunshine hours (monthly total) during the experimental period ranged from 16.8-26.8°C, 0.0- 915.2 mm, 76.1-83.3% and 147-192.4 h, respectively.

Experimental treatments and design: The experiment factors included 6 different plant nutrient management treatments viz., (1) No fertilizer/manure (control), (2) Recommended fertilizer (RF) (Urea at the rate of 250, TSP at the rate of 120, MOP at the rate of 100, Gypsum at the rate of 60 and zinc sulphate at the rate of 10 kg ha^{-1}), (3) 75% RF, (4) Compost at the rate of 10 t ha^{-1}, (5) Compost at the rate of 5 t ha^{-1}+75% RF and (6) Compost at the rate of 5 t ha^{-1}+50% RF and 3 fish species treatments such as (1) No fish, (2) Tilapia and (3) Common carp. The experiment was laid out in a randomized complete block design (RCBD) with 3 replications. Thus total number of plot was 54. Each plot size was 5 m×3 m. A shallow (50 cm depth) ditch of size 3 m×0.5 m was kept in each plot.

Materials used: One rice variety and two fish species were used as experimental materials in this study. A brief description of those materials has been presented in Table 1.

Rice culture: Healthy and vigorous seeds of BRRI dhan 29 were soaked in water for 24 h and then kept in gunny bags for seed sprouting. Sprouted rice seeds were sown in the wet nursery bed on 5, December, 2017. The experimental land was prepared by a power tiller 10 days before transplanting. It was then puddled well with the help of a country plough. Rice field was fertilized with chemical fertilizers and/or compost as per experimental treatments. Compost was applied before rice transplanting following incorporation with soil with the help of a spade. The full doses of TSP, MoP and gypsum and zinc sulphate were applied before transplanting as basal dose. Urea was top dressed in 3 equal splits, at 15, 30 and 45 days after transplanting (DATs). Forty days old seedlings were transplanted in the well prepared puddled field on 15 January, 2018 at the rate of three seedlings/hill maintaining row and hill distance of 25 and 15 cm, respectively. In case of rice-fish culture, rice seedlings were transplanted in 4.5 m×3 m area of each individual plot excluding the shallow ditch area of 3 m×0.5 m. While for rice sole culture, whole plot was transplanted with rice maintaining the same spacing. Weeding was done manually thrice at 20, 40 and 60 DATs. The crop was grown under fully irrigated condition. A water depth of 15-20 cm was maintained throughout the growing season to favor fish culture. While in the shallow ditches, the water depth was continuously around 50 cm. There were no remarkable infestations by insect pests or diseases during the crop growth period. Therefore, no plant protection measures were taken. The crop was harvested at full maturity when about 80% of the grains became golden yellow in color.

Fish culture: A small ditch was constructed to provide refuge during high water temperature and low depth water at the edge of each plot containing fish. The length, width and depth of the ditch was 3, 0.5 and 0.5 m, respectively. Before releasing of fingerlings, each plot was enclosed with net very carefully from the bottom of the mud to the top 1 m so that fished could not go away. The fingerlings of both tilapia and common carp (initial length of 6 and 8 cm and weight of 5.75 and 9.75 g, respectively) were collected from Bangladesh Fisheries Research Institute (BFRI). All fingerlings were released after 15 days of transplanting of rice (30th January, 2018). No artificial feed was supplemented for the growth of fish. The fishes were harvested on 29th June, 2018 after 150 days of release.

Observations made: Five rice hills (excluding border hills) were randomly selected from each plot and uprooted before harvesting for recording the necessary data on various plant characters. Growth parameters of rice like plant height and total tillers hill^{-1} and yield parameters such as, number of effective tillers hill^{-1}, number of grains/panicle, number of sterile spikelets/panicle, 1000-grain weight and grain, straw and biological yields and harvest index were recorded. Fish growth was recorded in terms of initial individual fingerling length, initial individual fingerling weight, final individual fingerling length, final individual fingerling weight, length gain (%), weight gain (%), length gain/day, weight gain/day and survival rate (%). After harvesting, fish yield was recorded and expressed as kg ha^{-1}. Different fish growth parameters were measured with the following equation[3].

Length gain (%): Percent length gain of every fish species was calculated using the following equation:

$$\text{Length gain (\%)} = \frac{\text{Final length of individual fish} - \text{Initial length of individual fish}}{\text{Initial length of individual fish}} \times 100 \quad (1)$$

Weight gain (%): Percent weight gain of every fish species was calculated using the following equation:

$$\text{Weight gain (\%)} = \frac{\text{Final weight of individual fish} - \text{Initial weight of individual fish}}{\text{Initial weight of individual fish}} \times 100 \quad (2)$$

Weight gain/day: Weight gain/day of every fish species was calculated using the following equation:

$$\text{Weight gain (day)} = \frac{\text{Final weight of individual fish} - \text{Initial weight of individual fish}}{\text{Growing period (150 days)}} \quad (3)$$

Survival rate: The survival rate was estimated by the following equation:

$$\text{Survival rate (\%)} = \frac{\text{Number of fishes harvested}}{\text{Number of fishes released}} \times 100 \quad (4)$$

Economic analysis: To study the economic performance of different rice-fish culture systems, total variable cost, gross return and net return were calculated based on the local market price of different inputs, products, by products and labor wages. Finally benefit cost ratio was calculated with the following equation:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return}}{\text{Variable cost}} \quad (5)$$

Statistical analysis: Collected data were compiled, tabulated and analyzed statistically. Analysis of variance (ANOVA) was done following the randomized complete block design (RCBD) with the help of computer package MSTAT and the mean differences among the treatments were adjudged by Duncan's multiple range test.

RESULTS

Performance of rice

Growth parameters: Rice growth was measured in terms of plant height and tillering ability. Plant height of BRRI dhan 29 was significantly affected by nutrient management but not by fish species and their interaction (Table 2 and 3). BRRI dhan 29 showed maximum plant height when fertilized with recommended fertilizer. At harvest culture of fish resulted in

Table 2: Effect of nutrient management and fish species on plant height, total tillers/hill and yield parameters of BRRI dhan 29

	Yield contributing characters				
Nutrient management	Plant height at harvest	Total tillers/ hill at harvest	No. of effective tillers/hill	Grains/ panicle	1000-grain weight (g)
No fertilizer/manure (control)	60.82^{d}	6.978^{c}	6.122^{c}	93.78^{d}	12.97^{e}
Recommended fertilizer (RF)	89.09^{a}	9.933^{a}	9.211^{a}	138.60^{a}	21.24^{a}
75% RF	77.13^{bc}	9.267^{ab}	8.244^{b}	126.00^{b}	20.27^{b}
Compost at the rate of 10 t ha^{-1}	64.48^{d}	8.544^{b}	7.533^{b}	113.30^{c}	16.47^{d}
Compost at the rate of 5 t ha^{-1}+75% RF	82.32^{b}	9.244^{ab}	8.156^{b}	129.90^{ab}	20.47^{b}
Compost at the rate of 5 t ha^{-1}+50% RF	74.52^{c}	8.767^{b}	7.644^{b}	123.10^{b}	19.57^{c}
Level of significance	**	**	**	**	**
CV (%)	8.89	10.55	11.05	7.51	3.29
Fish species					
No fish	72.70	8.44	7.44	113.50^{b}	18.22
Tilapia	75.74	8.97	8.03	124.90^{a}	18.67
Common carp	75.74	8.95	7.99	123.90^{a}	18.61
Level of significance	NS	NS	NS	**	NS
CV (%)	8.89	10.55	11.05	7.51	3.29

In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), **Significant at 1% level of probability, NS: Not significant

Table 3: Effects of interaction between nutrient management and fish species on plant height, total tillers/hill and yield parameters of BRRI dhan 29

Interaction		Yield contributing characters				
Nutrient management levels	Fish species	Plant height at harvest	Total tillers hill^{-1} at harvest	No. of effective tillers hill^{-1}	Grains panicle^{-1}	1000-grain weight (g)
No fertilizer/manure (control)	No fish	9.67	6.77	5.87	85.66	12.83
	Tilapia	61.87	7.13	6.30	96.00	13.10
	Common carp	60.93	7.03	6.20	99.66	12.97
Recommended fertilizer (RF)	No fish	88.27	9.57	8.87	132.66	20.73
	Tilapia	89.93	10.13	9.43	143.33	21.57
	Common carp	89.07	10.10	9.33	139.66	21.43
75% RF	No fish	75.00	8.87	7.70	117.33	20.03
	Tilapia	77.17	9.43	8.50	128.66	20.30
	Common carp	79.23	9.50	8.53	132.00	20.47
Compost at the rate of 10 t ha^{-1}	No fish	60.43	8.33	7.23	106.66	16.10
	Tilapia	67.03	8.53	7.60	116.33	16.77
	Common carp	65.97	8.77	7.77	117.00	16.53
Compost at the rate of 5 t ha^{-1}+75% RF	No fish	80.70	8.77	7.73	123.33	20.30
	Tilapia	82.23	9.63	8.50	136.00	20.43
	Common carp	84.03	9.33	8.23	130.33	20.67
Compost at the rate of 5 t ha^{-1}+50% RF	No fish	72.13	8.37	7.23	115.33	19.30
	Tilapia	76.20	8.97	7.83	129.00	19.83
	Common carp	75.23	8.97	7.87	125.00	19.57
Level of significance		NS	NS	NS	NS	NS
CV (%)		8.89	10.55	11.05	7.51	3.29

In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), NS: Not significant

numerically higher plant stature compared to sole rice culture. Like plant height, tillering ability of BRRI dhan 29 was also significantly affected by nutrient management, but was found independent of fish species and their interaction. Maximum tillering ability of BRRI dhan 29 was recorded when fertilized with recommended fertilizer.

Yield parameters: Yield contributing characters like number of effective tiller/hill and weight of 1000 grain of BRRI dhan 29 was significantly affected by nutrient management but not by fish species and their interaction (Table 2 and 3). Maximum number of effective tiller/hill of rice (9.211) was observed when rice was fertilized with recommended fertilizer, the lowest one (6.122) was found when no fertilizer/manure was applied (Control). On the other hand, the highest weight of 1000-grain (21.24 g) was found at recommended fertilizer treatment. Nutrient management and fish species exerted significant influence on the number of grain panicle^{-1} but not by their interaction (Table 1 and 2). The maximum number of grains panicle^{-1} (138.60) was recorded with recommended fertilizer which was statistically similar with that when fertilized with75% RF along with compost at the rate of 5 t ha^{-1}. Maximum number of grains/panicle (124.90) was observed in rice-tilapia culture.

Yield: Rice yield was evaluated in terms of grain weight/hill, grain yield, straw yield and biological yield. All those were significantly affected by nutrient management but not by fish species (except grain weight/hill) and their interaction (Table 4 and 5). The highest grain weight/hill (27.43 g), grain yield (6.54 t ha^{-1}), straw yield (6. 87 t ha^{-1}) and biological yield (13.41 t ha^{-1}) were found at recommended fertilizer treatment. The lowest values against all those were registered with no fertilizer treatment closely followed by application of only compost at the rate of10 t ha^{-1}. Fish culture only affected grain weight/hill. Highest grain weight/hill (19.56 g) was obtained in rice-tilapia culture statistically followed by rice-carp culture (19.31 g).

Performance of fish

Growth and yield of tilapia: Except survival rate (%), all the growth parameters and yield of tilapia were significantly influenced by different nutrient management (Table 6 and Fig. 1). Except the treatments 75% RF with compost at the rate of 5 t ha^{-1} and 50% RF with compost at the rate of 5 t ha^{-1}, all other treatments resulted in statistically similar and highest individual length, length gain, length gain/day of tilapia. On the other hand, all the nutrient managements except no fertilizer/manure (control) produced statistically similar and the highest individual weight, weight gain (%), weight

Table 4: Effect of nutrient management and fish species on yield of Boro rice cultivar BRRI dhan 29

Nutrient management levels	Grain weight hill^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
No fertilizer/manure (control)	7.599^{e}	2.07^{e}	2.571^{e}	4.651^{e}
Recommended fertilizer (RF)	27.43^{a}	6.54^{a}	6.87^{a}	13.41^{a}
75% RF	21.42^{b}	5.26^{b}	5.65^{b}	10.91^{b}
Compost at the rate of 10 t ha^{-1}	14.40^{d}	3.50^{d}	3.79^{d}	7.291^{d}
Compost at the rate of 5 t ha^{-1}+75% RF	22.02^{b}	5.25^{b}	5.57^{b}	10.83^{b}
Compost at the rate of 5 t ha^{-1}+50% RF	18.61^{c}	4.35^{c}	4.59^{c}	8.940^{c}
Level of significance	**	**	**	**
CV (%)	13.74	14.60	11.53	6.81
Fish species				
No fish	16.87^{b}	4.34	4.76	9.10
Tilapia	19.56^{a}	4.58	4.89	9.47
Common carp	19.31^{a}	4.58	4.87	9.45
Level of significance	**	NS	NS	NS
CV (%)	13.74	14.60	11.53	6.81

In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), **Significant at 1% level of probability, NS: Not significant

Table 5: Effects of interaction between nutrient management and fish species on yield of Boro rice cultivar BRRI dhan 29

		Interactions			
Nutrient management levels	Fish species	Grain weight hill^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
No fertilizer/manure (control)	No fish	6.83	1.91	2.36	4.26
	Tilapia	7.96	2.20	2.70	4.90
	Common carp	8.01	2.13	2.66	4.79
Recommended fertilizer (RF)	No fish	25.23	6.36	6.73	13.08
	Tilapia	29.14	6.66	7.03	13.69
	Common carp	27.93	6.60	6.86	13.46
75% RF	No fish	19.19	5.09	5.73	10.82
	Tilapia	22.11	5.31	5.57	10.88
	Common carp	22.95	5.38	5.66	11.04
Compost at the rate of 10 t ha^{-1}	No fish	13.07	3.42	3.82	7.23
	Tilapia	14.59	3.50	3.72	7.22
	Common carp	15.55	3.59	3.84	7.42
Compost at the rate of 5 t ha^{-1}+75% RF	No fish	20.04	5.04	5.53	10.57
	Tilapia	23.59	5.34	5.64	10.98
	Common carp	22.43	5.38	5.55	10.93
Compost at the rate of 5 t ha^{-1}+50% RF	No fish	16.88	4.24	4.40	8.64
	Tilapia	19.96	4.44	4.70	9.15
	Common carp	18.99	4.37	4.67	9.04
Level of significance		NS	NS	NS	NS
CV (%)		13.74	14.60	11.53	6.81

In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), NS: Not significant

Table 6: Effects of nutrient management levels on final individual length at harvest, percent length gain, length gain/day and percent survival rate of tilapia

Nutrient management levels	Survival rate (%)	Individual length at harvest (cm)	Length gain (%)	Length gain day^{-1} (g)	Individual weight at harvest (g)	Weight gain (%)	Weight gain day^{-1} (g)
No fertilizer/manure (control)	70.27	14.28^{a}	138.1^{a}	0.055^{a}	62.67^{b}	989.9^{b}	0.3800^{b}
Recommended fertilizer (RF)	71.07	14.77^{a}	146.2^{a}	0.058^{a}	79.96^{a}	1291.0^{a}	0.4967^{a}
75% RF	74.07	14.78^{a}	146.4^{a}	0.059^{a}	78.14^{a}	1259.0^{a}	0.4833^{a}
Compost at the rate of 10 t ha^{-1}	77.78	14.80^{a}	146.6^{a}	0.059^{a}	82.00^{a}	1326.0^{a}	0.5067^{a}
Compost at the rate of 5 t ha^{-1}+75% RF	75.10	13.24^{b}	120.6^{b}	0.048^{b}	84.80^{a}	1375.0^{a}	0.5300^{a}
Compost at the rate of 5 t ha^{-1}+50% RF	75.00	14.00^{ab}	133.3^{ab}	0.053^{ab}	83.67^{a}	1355.0^{a}	0.5200^{a}
Level of significance	NS	*	*	*	*	*	*
CV (%)	5.72	3.67	6.32	6.17	8.64	9.32	9.56

In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), *Significant at 5% level of probability, NS: Not significant

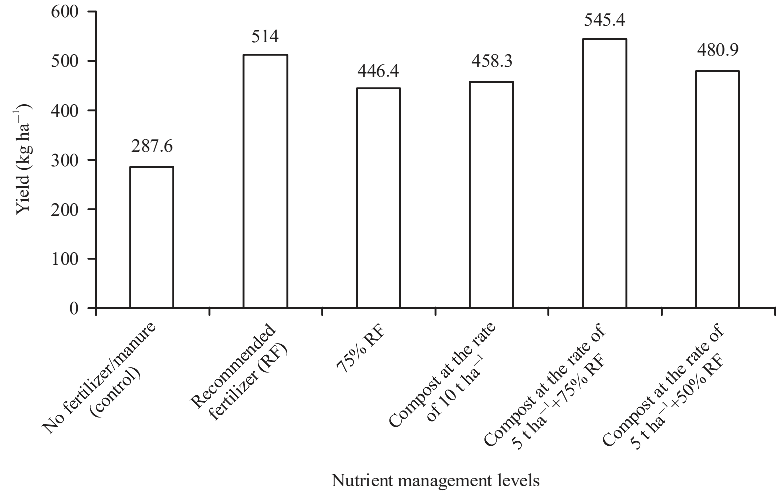

Fig. 1: Yield of tilapia in rice-fish culture under different nutrient management

Table 7: Effects of nutrient management levels on final individual length at harvest, percent length gain, length gain/day and percent survival rate of common carp

Nutrient management levels	Survival rate (%)	Individual length at harvest (cm)	Length gain (%)	Length gain day^{-1} (g)	Individual weight at harvest (g)	Weight gain (%)	Weight gain day^{-1} (g)
No fertilizer/manure (control)	75.00	18.53	117.96	0.067	84.89^{c}	770.70	0.501
Recommended fertilizer (RF)	77.03	19.93	134.51	0.076	94.67^{ab}	870.94	0.566
75% RF	80.03	18.92	122.55	0.069	90.07^{b}	823.76	0.535
Compost at the rate of 10 t ha^{-1}	84.10	17.59	106.90	0.061	95.10^{b}	875.38	0.569
Compost at the rate of 5 t ha^{-1}+75% RF	80.17	18.96	123.06	0.070	100.37^{a}	929.40	0.604
Compost at the rate of 5 t ha^{-1}+50% RF	79.11	18.90	122.39	0.069	96.83^{ab}	893.16	0.581
Level of significance	NS	NS	NS	NS	**	NS	NS
CV (%)	5.73	4.28	7.81	7.98	4.53	17.33	17.33

In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), **Significant at 1% level of probability, NS: Not significant

gain day^{-1}, of tilapia. Application of 75% RF with compost at the rate of 5 t ha^{-1} resulted in the highest yield (545.4 kg ha^{-1}) statistically followed by recommended fertilizer (514 kg ha^{-1}), while application of no fertilizer produced the lowest tilapia yield. The lowest yield of tilapia (287.6 kg ha^{-1}) was observed when no fertilizer/manure (control) was applied followed by application of 75% RF and only 10 t compost ha^{-1} (Fig. 1).

Growth and yield of carp: Only individual weight at harvest and yield of carp were significantly influenced by different nutrient management (Table 7 and Fig. 2). The highest individual weight at harvest (100.37 g) was found when fertilized with 75% RF with compost at the rate of 5 t ha^{-1} which was statistically followed by 50% RF with compost at the rate of 5 t ha^{-1} (96.83 g) and 100% RF (94.67 g). No fertilizer resulted in numerically the lowest carp yield (401.8 kg ha^{-1}), while application of 50% RF along with compost at the rate of 5 t ha^{-1} produced the highest carp yield (625.0 kg ha^{-1}) statistically followed by application of only compost at the rate of10 t ha^{-1} or 75% RF (Fig. 2).

Economic performance: Rice-fish culture resulted in higher net return and benefit cost ratio (BCR) compared to rice sole culture under any nutrient management. And, application of no fertilizer/manure or only compost produced very poor economic return. Net return was recorded positive in all cases (ranging from BDT 21.949-141,956 ha^{-1}) except for rice sole culture grown without any fertilizer/manure (BDT-20, 240 ha^{-1}) and with only compost at the rate of 10 t ha^{-1} (BDT 11380 ha^{-1}). The BCR was also recoded>1 for all the treatments (varied between 1.18 and 2.09) except for rice sole culture under no fertilizer/manure (0.72) and fertilized with only compost at the rate of 10 t ha^{-1} (0.99). Although the maximum net return (BDT 141,956 ha^{-1}) was obtained from rice-carp culture under recommended fertilizer, but highest BCR (2.09) was achieved from rice-tilapia culture under recommended fertilizer closely followed by rice-carp culture (2.03) under recommended fertilizer. On the other hand, rice sole culture under no fertilizer management resulted in lowest BCR (0.72) followed by rice sole culture fertilized with only compost at the rate of 10 t ha^{-1} (0.99) (Table 8).

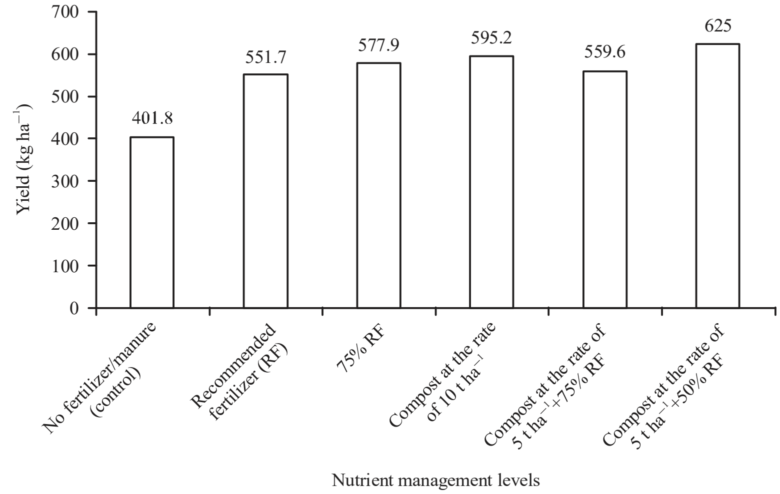

Fig. 2: Yield of common carp in rice-fish culture under different nutrient management

Table 8: Cost benefit analysis of rice-fish culture under different nutrient management

Treatment combinations		Total variable cost (BDT ha^{-1})			Gross return (BDT ha^{-1})			Net return (BDT ha^{-1})	Benefit cost ratio
Nutrient management	Fish species	Rice	Fish	Total	Rice	Fish	Total		
No fertilizer/manure	No fish	73500	0	73500	53260	0	53260	-20240	0.72
	Tilapia	73500	26400	99900	61200	62445	123645	23745	1.24
	Common carp	73500	47000	120500	59620	82829	142449	21949	1.18
Recommended fertilizer (RF)	No fish	90925	0	90925	168320	0	168320	77395	1.85
	Tilapia	90925	26400	117325	176120	69522	245642	128317	2.09
	Common carp	90925	47000	137925	173680	106201	279881	141956	2.03
75% RF	No fish	86569	0	86569	137460	0	137460	50891	1.59
	Tilapia	86569	26400	112969	140140	62113	202253	89284	1.79
	Common carp	86569	47000	133569	142120	101382	243502	109933	1.82
Compost at the rate of 10 t ha^{-1}	No fish	93500	0	93500	92120	0	92120	-1380	0.99
	Tilapia	93500	26400	119900	92760	61206	153966	34066	1.28
	Common carp	93500	47000	140500	95340	83242	178582	38082	1.27
Compost at the rate of 5 t ha^{-1}+75% RF	No fish	96569	0	96569	134960	0	134960	38391	1.40
	Tilapia	96569	26400	122969	141240	48708	189948	66979	1.54
	Common carp	96569	47000	143569	141240	89823	231063	87494	1.61
Compost at the rate of 5 t ha^{-1}+50% RF	No fish	92213	0	92213	111520	0	111520	19307	1.21
	Tilapia	92213	26400	118613	117520	54536	172056	53443	1.45
	Common carp	92213	47000	139213	116020	103903	219923	80710	1.58

BDT: Bangladeshi Taka, 1US$: BDT 85 (approx.)

DISCUSSION

Rice-fish farming is the best example of integration where both the components are mutually benefited and thus is a sustainable option for increasing rice and fish production through less use of land and water. Integration of fish with rice farming not only improves diversification and intensification but also increases system productivity and profitability and ensures sustainability[16]. Fertilizer is the cheapest means of increasing aquatic productivity and a prerequisite for commercial fish culture. Fertilizers, mostly inorganic ones increase plankton population, the basis of food chain in an aquatic ecosystem. Therefore, fertilizer management in rice-fish integrated farming is very crucial for enhancing system productivity. But some farmers use sub-optimal doses while others apply much higher than the required dose for more profit. In the present study an attempt was therefore made to optimize fertilizer requirement for increasing rice-tilapia and rice-carpio productivity.

In this study, rice grain weight produced by individual hill was increased due to integration of fish although rice yield/unit area remain unchanged between rice sole and rice-fish culture, because plant population was lower in rice-fish culture for keeping ditches. This was happened because integration of fish favored the growth and productivity of rice component in different ways. Integration of fish with rice in a managed way have several advantages including better control of harmful insects, pests and weeds[17,18] and increased soil fertility by adding organic excreta which result in increased rice yield. Lightfoot *et al*.[2] concluded that rice-fish farming offers possibilities of increasing rice yields by up to 15% and harvesting up to 500 kg ha^{-1} of fish. Fish culture in rice field enhances soil fertility resulting increased rice yield ranging from 10-15% as compared to rice sole culture[19,20]. Halwart[10] confirmed additional income from rice-fish integrated farming. Many reports confirm that fish improve soil fertility by increasing the availability of nitrogen and phosphorus[5,6] which might contribute to increased rice yield. On the other hand, fish is also benefited in rice-fish culture. Rice fields provide epiphytic and benthic food for fishes[8] and rice plants provide shade that maintains water temperature favorable for fish during hot days of summer[9] and thus both are mutually benefited.

Fertilization in rice-fish farming is very crucial issue due to involvement of many factors determining system productivity and sustainability. Rice-fish farming is characterized by recycling of nutrients, proper utilization of resources and soil fertility due to accumulation of nitrogen[11,21]. Application of fertilizers benefits both rice and fish. The supplied nutrients through fertilizers directly increase phytoplankton growth which either supports zooplankton production or is directly consumed by the fish. Integration of fish in the rice field actually boosts rice field fertility and lower fertilizer requirements. Wu[13] reported from china that organic, alkaline and total nitrogen in the soil are consistently higher in rice-fish culture than in rice sole culture. In addition to supplying nutrients, the particles from organic fertilizers also act as substrates for the growth of epiphytic fish food organisms.

As evident from this study, productivity of fish in rice-fish integrated farming can be increased by proper application of fertilizers in rice field. Similar findings have been reported by Sanh *et al*.[22], Wahab *et al*.[23], Miah *et al*.[24] and Sayeed *et al*.[25]. Fertilization is mostly done to augment the production of plankton which serves as natural food for the fishes[26]. Saha *et al*.[27] concluded that chemical fertilizers enhanced the growth of phytoplankton more than that of zooplankton which in turn results in higher growth of fish. As stated by Ekram[28], production of fish can be boosted up to 5,000 kg ha^{-1} by feeding as well as fertilization. Inorganic fertilizers increase mainly the phytoplankton populations of water body and inorganic fertilizers, on the other hand dissolve more readily in water and accelerate the nutrient supply in the aquatic environment. Therefore, integration of chemical fertilizers (like urea, TSP) with inorganic fertilizers (such as cow dung, poultry manure) is necessary for higher fish yield[23,29]. However, productivity of either fish species was not so high. This was might be due to not supplying any supplementary fish feed and low stocking density.

In this study survival rates of tilapia or carp was not affected by nutrient management and ranged between 70 and 84%. Similar survival rate of fish in rice culture has been reported by many researchers[30]. Akhteruzzaman *et al*.[31], on the other hand, observed only 50-53% survival rate. Survival rate of fingerlings mostly depends on the dissolved oxygen concentrations in water and may be dissolved oxygen concentrations were similar (although not monitored) in case of all the fertilizer treatments which might result in similar survival rate of fishes.

As observed, fertilization with recommended doses (of chemical fertilizers) resulted in the highest grain yield of rice and application of only organic fertilizer (compost) yielded the lowest. This was very much expected because the poor fertility status of the experimental soil was not enough to produce potential yield when fertilized with only organic manures. On the other hand, application of recommended fertilizers ensured the supply of sufficient nutrients required for proper rice growth to produce potential yield. This is supported by the findings of Ahmed *et al*.[32], Shaon *et al*.[33], Jahan *et al*.[34] and Ferdous *et al*.[35]. However, contrasting findings have also been reported by Ahsan *et al*.[36], Yeasmin *et al*.[37] and Islam *et al*.[38] where integration of different organic manures with recommended or 50-70% of recommended fertilizer yielded the best. This was might be due to the variation in the soil fertility status among the research sites.

Rice-fish farming was found more remunerative than rice sole culture because return from fish component was much higher than the cost involved for integrating fish in rice culture; moreover, integration of fish did not reduce rice yield. In case of no fertilizer, BCR was very low due to very poor rice yield, while application of recommended fertilizer resulted in high BCR which was the consequence of high rice yield. Findings of this study are strongly agreed with those of Islam *et al*.[30], Hossain and Joadder[39] and Mridha *et al*.[40].

CONCLUSION AND FUTURE RECOMMENDATION

Rice-fish culture was found more remunerative than rice sole culture in terms of net return and benefit cost ratio. Therefore, considering the productivity and profitability, either tilapia or common carp can be integrated with rice following fertilization with recommended doses of chemical fertilizers.

In this study, fish was cultured in rice field based on natural food without any supplementation of artificial feed and consequently fish growth and yield were not satisfactory although remunerative. Therefore, further research to determine feeding rates and optimize suitable stocking density in rice-fish culture is necessary to increase the system productivity.

SIGNIFICANCE STATEMENT

This study confirms that application of recommended chemical fertilizer for rice has no adverse effect on the productivity of tilapia or common carp in rice-fish farming. Findings of the present study will help the researchers to further explore the different dimensions of plant nutrient dynamics in relation to system productivity, water quality and ecosystem sustainability of rice-fish integrated farming. Thus, a new theory on the sustainable nutrient management for commercial rice-fish farming may be arrived at.

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