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Impact on environment intervention of carps-sis polyculture in north-west of Bangladesh

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Abstract
This study was carried out in different water bodies to assess production potentials on carp-mola polyculture commonly found from July-December 2012. Pond and pond like inundated rice plots were employed for the experiment. It was comprised of three treatments with having 12 replicate in two districts. The examined species: rohu (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus cirrhosus*), silver carp (*Hypophthalmichthys molitrix*), silver barb (*Barbodes gonionotus*), bata (*Labeo bata*) and mola (*Amblypharyngodon mola*) were stocked in both pond and rice field. The two treatments were utilized by rice-fields with carps-mola (T_1 - RCM) and only carps (T_3 - RC) and other treatment by ponds with carps-mola (T_3 - PCM). The stocking rate of all carps were 20/dec. in all rice plots of two treatments (T_1 & T_3) but in ponds 40/dec. Whereas, mola stocked same rate (150g/dec.) of all treatment. Five important water quality parameters were measured monthly interval. Temperature, pH and alkalinity were significantly differences but transparency and DO were not varied significantly among all the treatments. The gross production of fishes was the highest (3157.96 kg ha^{-1}) in T_2 where carp-mola polyculture represent in ponds with double stocking rate of carps from rice-field. But among the all carps species were the highest harvesting weight in rice-fields. And also from the total production of mola was the highest (20%) in T_1 between Rice-field (T_1) and ponds (T_2) treatments. Subsequently, other SIS production was the highest in T_3 treatment where not stocked small fish. As higher production and their high market value of mola boost up the BCR (3.43) in T_1 among all treatments. Hence, it is summarized that pond like alternate rice plot are more abundance of natural food which enhance the production both carps and mola as well.

Keywords: Impact, environment intervention of carps-sis polyculture, different water bodies to assess production

Introduction

The ever-growing population in many developing countries like Bangladesh has necessitated harnessing of all available resources for increased production of food to meet the current and future demand. Of late, fisheries resources have been emerged as a potential source not only for increased food production but also for generation of income. Fisheries sector is the second to agriculture in importance. The country is endowed with about 47 lac ha inland waters including 4 lac ha ponds and 68,000 ha floodplain (DoF, 1014) which those water bodies are promising culture potentials. Aquaculture, as a relatively recent science, is still being practiced along traditional extensive lines in Bangladesh and fish polyculture is the main form of aquaculture production system. Fish polyculture in the country is done on an ad-hoc basis considering mainly the relationships among the target species feeding at different levels of food chain, but often with little concern of appropriate management related to its complex combination of nutrient loading, its dynamics in regulating water quality and biological productivity in the ecosystem.

The low lying rice field is a unique aquatic environment. It has a standing column of water and a natural plankton growth in it, in addition to its insect and mollusks, which serve as fish food. The main aquaculture production of Bangladesh comes from pond and ditches (85%), it also has an area of 10.14 million ha of irrigated and rainfed rice fields where aquaculture could potentially be integrated concurrently and/or alternately to rice production (Rahman 1995) [33]. A flooded rice field is a productive ecosystem that can sustain a variety of aquatic organisms including fish (Fernando 1993) [15]. Fish itself are generally presumed to have a beneficial effect on the rice production (Ruddle 1982; Lightfoot, van Dam & Costa-Pierce 1992a) [36, 26]. The Indian major carps rohu, catla, mrigal and silver carp are very popular fish in this subcontinent due to their good taste. The present experiment using a combination of Indian major and minor carps with nutritious mola and darkina considering more economic and nutritional benefits. Using this combination, farmers can benefit by selling the carps, mola and darkina and also meet their nutritional demands. Mola & darkina propagate naturally two to three times in a year under normal pond condition and rice-fields.

Small indigenous species (SIS) of fish are important to the rural poor in many countries of Asia as they are relatively cheap, are consumed whole and have higher nutritive value than many cultured species (Hossain, 1998) [17]. Small indigenous species have several additional advantages, including self-recruitment, being fast growing, feeding at low trophic levels and having a high content of micronutrients, including calcium and vitamin A (Thilsted & Hassan 1993; Thilsted, Ross & Hassan 1997) [38, 39]. Rural people of many South Asian countries including Bangladesh, consume 56-73 species of SIS (Minkin, 1993) [28], among which mola, darkina, chela, punti etc. are most commonly preferred.

Alternate farming involves producing fish in rice fields during the monsoon. Fish fingerlings are stocked in June- July and are harvested primarily from November to December, a culture period of around 5–7 months. Some farmers avoid fish culture with boro rice during the dry season from January to April, because of the lower availability of fish fingerlings. Some other farmers avoid cultivation of monsoon season aman rice with fish because of high water levels (up to 1.5 m). It is also thought to reduce fish growth, competing with fish for living space and placing demands on the farmer's limited capital. However, culture of deepwater rice with fish during the flood season, followed by dry season rice farming can be established in flood-prone rice field ecosystems (Dugan *et al*. 2006) [12].

Fish and rice are cultivated alternatively one following the other. In this the disadvantages of the growing together are eliminated and the advantages of growing separately are enhanced. Both could be given better care and management and the use of mechanical means of production, use of modern agricultural techniques also can be employed. After the rice is harvested, the field may require some repair and maintenance. Then the field is filled with water and is transformed into like fish pond following the manuring and fertilization methods usually employed for the fish culture. At the time of rice harvesting the stalks of the paddy plants should be completely removed, otherwise they will rotten and the water will be unfit for fish cultivation.

Considering the importance both pond aquaculture and alternated rice field like pond could provide economical, environmental and nutritionally viable alternatives for resource-poor farmers. From that two environment are comparable the production potentials for carp-SIS polyculture in Bangladesh.

Materials and methods

Experimental sites

This study was carried out in 24 farmers' rice plots and 12 farmers' ponds in Rangpur and Dinajpur district, Bangladesh. In comparison with ponds and alternate method of rice-fish culture systems *i.e.* there is no rice in the plots were followed in this experiment. Agro-ecology of the study area almost level, with 60-90 cm local differences in elevation. Relief is locally irregular near entrenched river channels. Mean annual rainfall is highest in the north east (2000mm). Mean annual temperature is about 25^0C. Highland 30%, Medium highland 55%, Medium lowland 4%, Lowland 2%, Homestead and water bodies 9%. The predominant soils have grey, silty, puddled topsoil and ploughpan. Organic matter content is generally low (<1.5%). Very small amount of surface water are available in rivers and tanks for dry season irrigation. Ground water resources are generally better for aquaculture.

Pre-stocking preparations

After harvesting of the boro rice, plots were modified by constructing earth embankments (1.5 m height and 1.0 m width) while ditches (1 m depth and 10-15% of the total area) were dogged up. About 10 cm rice straw and roots were left in the plots and afterward decomposed with rain water and in case of using deep tube-well water. Passing after 20-30 days, rice harvest when water level rose up to 30-60 cm by rainfall, liming was applied at the rate of 125 kg ha^{-1}. Next to seven days, plots were fertilized with semi-decomposed cow manure, urea and triple super phosphate (TSP) at the rate of 500, 25 and 25 kg ha^{-1}, respectively.

Experimental design

The experiment was consisted three treatments- in comparison of production performance among the rice-fields and ponds: combination with or without mola. It was performed simultaneously in total 12 rice-fields and 6 ponds with 6 replicates of each treatment both in Dinajpur and Rangpur district. This experiment was consisted of total 24 rice fields and 12 ponds along with 150 days from July to December 2012. Carp fingerlings were stocked in all the treatments but molas were stocked only T_1 and T_2 treatment. T_1: *Rice-fields with carp & mola* (RCM) –The average total area rice-fields (48.42 dec.). It consists of 12 rice plots. The stocking density (20/dec.) of carps: rohu (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus cirrhosus*), silver carp (*Hypophthalmichthys molitrix*), silver barb (*Barbodes gonionotus*), bata (*Labeo bata*) and mola (*Amblypharyngodon mola*) were 5, 3, 5, 3, 2, 2 in number and 150g per decimal, respectively. T_2: *Ponds with carp & mola* (PCM) – The average total area of ponds (13.25 dec.). It consists of 12 ponds. The ponds were situated far from the farmer's house that is comparatively near from the rice-fields area. The Stocking density (40/dec.) of indian major and minor carps: rohu, catla, mrigal, silver carp, silver barb, bata, and of mola were 10, 10, 8, 6, 4, 2 in number and 150g per decimal, respectively. T_3: *Rice-fields with carp* (RC) - The average total area rice-fields (72.92 dec.). It consists of 12 rice plots. Carps were stocked as like as treatment T_1. Molas were not stocked in this treatment. The entire stocking pattern has been presented in Table 1.

Table 1: Stocking characteristics with 12 replicates: species composition in average number and mean weight (g) of different treatments.

Fish species	Treatment					
	T_1 – RCM		T_2 - PCM		T_3 - RC	
	No. (20/dec.)	Wt. (g)	**No. (**40/dec.)	Wt. (g)	**No.** (20/dec.)	Wt. (g)
Carps						
Rui	242 (25%)	13.00	133 (25%)	13.50	365 (25%)	16.17
Catla	145 (15%)	16.00	80 (25%)	15.08	219 (15%)	14.50
Mrigal	242 (25%)	15.17	133 (20%)	16.00	365 (25%)	16.00
S. carp	145 (15%)	15.00	106 (15%)	14.00	219 (15%)	14.50
S. barb	97 (10%)	18.17	27 (10%)	14.17	169 (10%)	14.50
Bata	97 (10%)	13.33	53 (5%)	11.33	146 (10%)	09.83
Small fishes						
Mola	-	150g, NC	-	150g, NC	-	-

*RCM- Rice-field with Carp & Mola, PCM- Pond Carp & Mola, RC- Rice-field with carp, NC-Not Counting

Stocking and management of water & fishes

Farmers were bought carps fingerlings (10-20 g) form local fingerlings traders who collected them from rural nurseries. Fingerlings of the small fishes mola (1-3 g) where collected from perennial ponds & rice-field of the near-by farmers, where farmers keep them together with major carps and the small fishes naturally breed. During the experiment, lime was applied only in the pond two times. No commercial feed was applied but mustard oil cake were applied both pond and rice-fields irregular basis as per the ability of farmers' economic condition. To maintain natural food in the rice plots and ponds, fertilization with urea & TSP were done two times at the rate of 25 kg ha^{-1}, 12.5 kg ha^{-1}, respectively entire the experiment. In case of emergency in flood, the embankment of some ponds and rice fields were repaired.

Sampling of fishes

Fishes were sampled (10-20 individuals of each species) by seine net/cast net at monthly intervals to assess their growth (length and weight) by measuring scale & electronic balance (HC-K5KA), respectively and overall health condition.

Water quality monitoring

Water quality parameters (*i.e.* temperature, transparency, pH, DO and alkalinity) of each rice-plot & pond were performed every month between 9:00 and 11:00 AM. Water temperature was recorded with a Celsius thermometer. Transparency was measured from the ditches of rice field with a Secchi disc of 20 cm diameter in. Alkalinity and DO of water samples were measured by Portable kit (HANNA). pH was also measured by portable pH meter (HANNA).

Harvesting of fish

After three months from stocking, large carps were harvested small amount twice or thrice in a month for household consumption but farmers used to record properly. Partial harvesting of mola started two months after stocking for family consumption and for sell as brood fish. Farmers were concerned about partial harvesting of mola. It was interesting that those farmers' have got more production than others who harvest at the end. Total fish harvesting was carried out on last week of December'12. At final harvesting, all large fishes were weighed separately but mola was bulk weighed and add all the partial harvesting. The following parameters were used to evaluate the growth of fishes:

1. Weight gain (g) = Average final weight (g) - average initial weight (g)

2. Survival rate (%) = $\frac{\text{No. of fish harvested}}{\text{Initial no. of fishes}} \times 100$

3. Specific growth rate (%) = $\frac{\log_e W2 - \log_e W1}{T2 - T1} X100$ (Brown, 1957)

Here,
W_1= the initial live body weight (g) at time T_1 (day)
W_2= the final live body weight (g) at time T_2 (day)

4. Gross Yield = No of fish caught × Average final weight
5. Net Yield = No of fish caught × Average weight gained

Benefit-cost (BCR) analysis

An economical analysis of different treatments was performed on the basis of the expenditure incurred and the total estimated return from the selling price of carps and mola. All input costs were recorded. The net benefit was calculated using the following formula: Net benefit = total sale – total investment. Benefit-cost ratio (BCR) was calculated as:

$$BCR = \frac{Total\ revenue}{Total\ cost}$$

Statistical analysis

Water quality parameters and fish yield parameters were compared using one-way ANOVA. Since the experimental pond sizes were different, pond size was used as covariate during the ANOVA (Gomez and Gomez, 1984) [16]. The percentage data were arc-sine transformed. If main effects were significantly different, differences among the treatments were tested with Tukey's multi-comparison test of means. The analyses were run at 5% significance level using statistical package (SPSS version 20.00).

Results

Water quality parameters

The mean values of each water quality parameters and their comparison (ANOVA) of all treatments during the entire experimental period are shown in Table 2. And also mean fluctuation values of those parameters (*i.e* water temperature, transparency, pH, DO and total alkalinity) are shown in Fig 1-5.

Temperature

The fluctuation trend of water temperature under different treatments was observed similar throughout the experiment. The values of water temperature ranged from 23-36, 19-33 and 21-34 ^{0}C in T_1, T_2 and T_3, respectively. The temperature of T_1 treatment was above than the other two treatments from beginning to end during the experiment (Fig. 1).

Table 2: Mean values (±SE) and range of some water quality parameters in different treatments

Parameter	T_1	T_2	T_3	F-value	Level of Sign./r^2
Temperature (^{0}C)	29.38 ^{a} ±0.43 (23.00-36.00)	27.53 ^{b} ±0.50 (19.00-33.00)	27.80 ^{ab} ±0.49 (21.00-34.00)	4.316	* 0.029
Transparency (cm)	29.65 ^{a} ±0.62 (20.00- 42.00)	28.65 ^{a} ±0.72 (18.00-47.00)	27.80 ^{a} ±0.67 (20.00-51.00)	1.878	NS 0.021
pH	8.06^a (7.09-9.18)	7.70^b (6.78-8.81)	8.09^a (6.12-9.10)	10.170	*** 0.001
DO (mg L^{-1})	4.84 ^{a} ±0.14 (2.50-7.50)	4.56 ^{a} ±0.13 (2.70-6.50)	4.90 ^{a} ±0.14 (2.10-7.30)	1.635	NS 0.001
Alkalinity (mg L^{-1})	102.61 ^{a} ±2.59(54.00-135.00)	87.85 ^{b} ±1.96 (54.00-123.00)	96.98 ^{a} ±2.23 (57.00-131.00)	10.276	*** 0.015

Significance level: (+) $P \leq 0.1$, * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$, P>0.05=NS, not significant

r^2= coefficient of determination

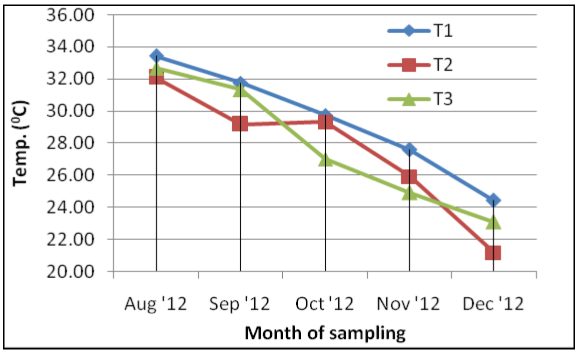

Fig 1: Mean value of water temperature in different treatments

Transparency

The mean values of transparency were determined 29.65 ±0.62, 28.65 ±0.72 and 27.80 ±0.67 cm in T_1, T_2 and T_3, respectively. The highest and lowest mean value was observed in pond (T_2) during in September and December, respectively (Fig. 2).

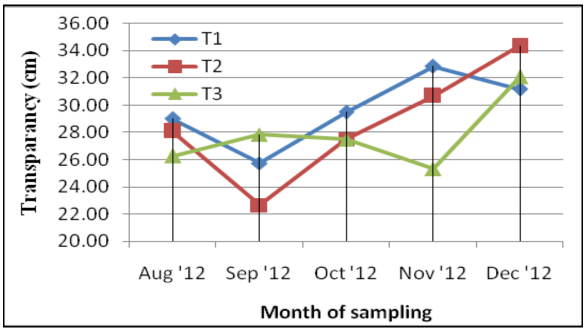

Fig 2: Month-wise mean water transparency in different treatments

Ph

The values of pH were recorded to vary from 7.09-9.18, 6.78-8.81 and 6.12-9.10 in T_1, T_2 and T_3, respectively, with the corresponding treatment means of 8.06, 7.70 and 8.09. About four sampling months were lower level of pH in T_2 treatment except in October (Fig. 3).

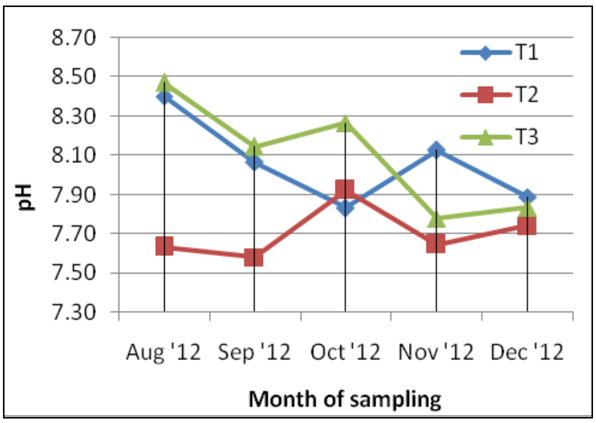

Fig 3: Mean value of water pH in different treatments

DO

The more fluctuated of DO concentration was observed in different treatments during the experiment. But the last month was very close among the treatments. The lowest value of DO was October as the value of pH (Fig. 4).

Alkalinity

The mean values of total alkalinity were measured 102.61±2.59 in T_1, 87.85±1.96 in T_2 and 96.98 ±2.23 in T_3 (Fig. 5). The total alkalinity values were higher at the 2nd sampling month of the experiment and then following a gradual decrease towards the end. The alkalinity value was the lowest (T_3) in November.

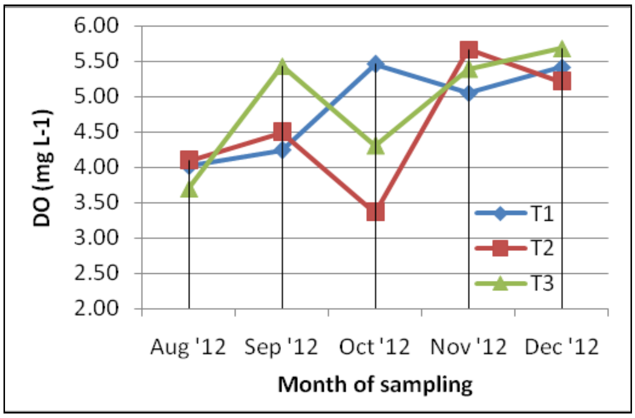

Fig 4: Mean value of water DO in different treatments

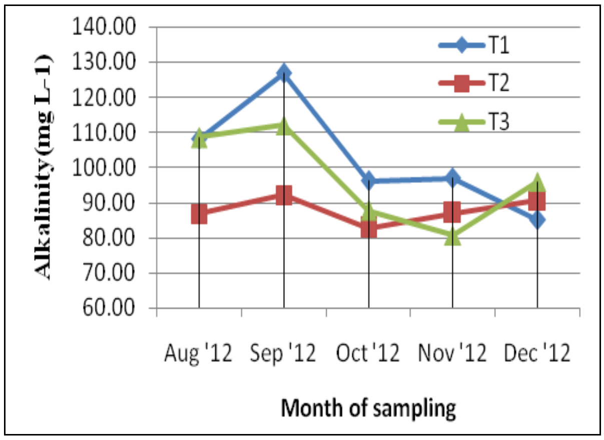

Fig 5: Mean values of alkalinity in different treatments

Growth performance of fishes

Mean multicomparison results of different growth parameters and production of all experimental species were shown in Table 3 & 4 using one way ANOVA and independent sample t-test, respectively among the treatments.

During the commencing of the experiment, the initial growth parameter was determined by initial stocking weight. That parameter of rui was varied 13.00 ±0.40, 13.50 ±0.71 and 15.08 ±0.51 g in T_1, T_2 and T_3, respectively. The initial stocking weight was significantly differed with the treatments. The individual harvesting weight was

Table 3: Mean (±SE) multicomparison of yield parameters of rui, catla, mrigal, silver carp, silver barb, bata, mola and other SIS in different treatments

Sp.	Treatment/ Growth parameter	T_1	T_2	T_3	Level of Sign. / r^2
RUI	Individual stocking wt. (g)	13.00 ^{b} ±0.40	13.50 ^{ab} ±0.71	15.08 ^{a} ±0.51	* / 0.171
	Individual harvesting wt. (g)	386.41 ^{a} ±12.85	252.00 ^{c} ±10.37	342.66 ^{b} ±9.44	*** / 0.072
	Weight gain (g)	373.41 ^{a} ±12.70	238.50 ^{c} ±10.18	326.50 ^{b} ±9.20	*** / 0.083
	SGR (% bwd^{-1})	2.26 ^{a} ±0.23	1.95 ^{b} ±0.04	2.03 ^{b} ±0.01	*** / 0.331
	Survival (%)	76.91 ^{a} ±2.61	72.58 ^{a} ±1.73	71.33 ^{a} ±0.66	NS / 0.120
	Gross yield (kg ha^{-1})	367.47 ^{b} ±18.16	449.50 ^{a} ±17.38	301.79 ^{c} ±8.68	*** / 0.115
	Net Yield (kg ha^{-1})	351.42 ^{b} ±18.04	416.16 ^{a} ±17.04	281.83 ^{c} ±8.30	*** /---
Catla	Individual stocking wt. (g)	16.00 ^{a} ±0.34	15.08 ^{a} ±0.25	14.91 ^{a} ±0.48	NS / 0.110
	Individual harvesting wt. (g)	398.25 ^{a} ±23.66	336.41 ^{ab} ±17.35	300.66 ^{b} ±17.37	** / 0.270
	Weight gain (g)	382.25 ^{a} ±23.61	321.33 ^{ab} ±17.32	286.16 ^{b} ±17.55	** / 0.263
	SGR (% bwd^{-1})	2.13 ^{a} ±0.04	2.06 ^{a} ±0.03	2.01 ^{a} ±0.04	NS / 0.106
	Survival (%)	71.25 ^{b} ±1.50	81.33 ^{a} ±1.60	71.00 ^{b} ±1.10	*** / 0.000
	Gross yield (kg ha^{-1})	211.40 ^{b} ±14.60	405.82 ^{a} ±18.38	157.73 ^{c} ±8.68	*** / 0.035
	Net Yield (kg ha^{-1})	199.54 ^{b} ±14.59	383.47 ^{a} ±18.29	146.98 ^{c} ±8.80	*** / 0.037
Mrigal	Individual stocking wt. (g)	15.16 ^{a} ±0.27	16.00 ^{a} ±0.49	16.00 ^{a} ±0.57	NS / 0.046
	Individual harvesting wt. (g)	465.41 ^{a} ±16.01	276.00 ^{b} ±12.49	344.25 ^{b} ±28.32	*** / 0.231
	Weight gain (g)	450.25 ^{a} ±16.05	260.00 ^{b} ±12.58	328.25 ^{b} ±28.37	*** / 0.232
	SGR (% bwd^{-1})	2.27 ^{a} ±0.02	1.89 ^{b} ±0.04	2.02 ^{b} ±0.06	*** / 0.211
	Survival (%)	76.75 ^{ab} ±1.46	80.25 ^{a} ±1.34	72.83 ^{b} ±1.00	*** / 0.093
	Gross yield (kg ha^{-1})	441.80 ^{b} ±19.25	545.53 ^{a} ±23.58	310.68 ^{c} ±27.05	*** / 0.012
	Net Yield (kg ha^{-1})	423.07 ^{b} ±19.03	506.01 ^{a} ±24.13	290.92 ^{c} ±27.21	*** / ---
Silver Carp	Individual stocking wt. (g)	15.00 ^{a} ±0.59	14.00 ^{a} ±0.73	14.50 ^{a} ±0.41	NS / 0.010
	Individual harvesting wt. (g)	584.16 ^{a} ±19.03	373.50 ^{b} ±27.29	601.25 ^{a} ±32.94	*** / 0.003
	Weight gain (g)	569.16 ^{a} ±19.24	359.50 ^{b} ±26.71	586.75 ^{a} ±32.59	*** / 0.003
	SGR (% bwd^{-1})	2.44 ^{a} ±0.03	2.17 ^{b} ±0.02	2.47 ^{a} ±0.02	*** / 0.005
	Survival (%)	76.58 ^{b} ±2.19	83.83 ^{a} ±1.07	79.16 ^{ab} ±1.33	* / 0.030
	Gross yield (kg ha^{-1})	330.54 ^{b} ±12.47	616.64 ^{a} ±42.52	354.67 ^{b} ±22.88	*** / 0.004
	Net Yield (kg ha^{-1})	319.43 ^{b} ±12.63	588.98 ^{a} ±41.34	343.93 ^{b} ±22.62	*** /---
Silver Barb	Individual stocking wt. (g)	18.16 ^{a} ±0.68	14.16 ^{b} ±0.50	14.50 ^{b} ±0.48	*** / 0.330
	Individual harvesting wt. (g)	308.66 ^{b} ±11.27	294.16 ^{b} ±4.71	374.41 ^{a} ±16.53	*** / 0.260
	Weight gain (g)	290.50 ^{b} ±11.32	282.75 ^{b} ±5.64	359.91 ^{a} ±16.80	*** / 0.284
	SGR (% bwd^{-1})	1.88 ^{c} ±0.03	2.02 ^{b} ±0.02	2.16 ^{a} ±0.04	*** / 0.445
	Survival (%)	79.50 ^{a} ±0.90	71.83 ^{b} ±0.94	75.16 ^{b} ±1.26	*** / 0.143
	Gross yield (kg ha^{-1})	121.50 ^{ab} ±5.25	104.49 ^{b} ±2.52	139.29 ^{a} ±7.21	*** / 0.102
	Net Yield (kg ha^{-1})	112.53 ^{b} ±5.32	97.49 ^{b} ±2.54	132.12 ^{a} ±7.53	*** / 0.122
Bata	Individual stocking wt. (g)	13.33 ^{a} ±0.37	11.33 ^{b} ±0.33	11.00 ^{b} ±0.32	*** / 0.382
	Individual harvesting wt. (g)	139.33 ^{a} ±9.63	116.33 ^{b} ±2.37	115.00 ^{b} ±1.72	** / 0.199
	Weight gain (g)	126.00 ^{a} ±9.70	105.00 ^{b} ±2.49	105.16 ^{b} ±1.72	* / 0.152
	SGR (% bwd^{-1})	1.55 ^{a} ±0.05	1.55 ^{a} ±0.02	1.64 ^{a} ±0.01	NS / 0.086
	Survival (%)	74.00 ^{a} ±3.72	75.25 ^{a} ±2.46	72.16 ^{a} ±0.91	NS / 0.007
	Gross yield (kg ha^{-1})	90.95 ^{a} ±5.25	86.53 ^{a} ±3.41	40.95 ^{b} ±0.55	*** / 0.635
	Net Yield (kg ha^{-1})	84.36 ^{a} ±5.27	75.33 ^{a} ±3.40	36.09 ^{b} ±0.59	*** / 0.664
Mola	Gross yield (kg ha^{-1})	503.78±33.33	535.68±37.80	-	NS / 0.063
	Net Yield (kg ha^{-1})	465.73±33.33	498.63±37.80	-	NS / 0.020
Other Sis	Gross yield (kg ha^{-1})	448.49 ^{a} ±20.52	395.75 ^{a} ±29.45	483.28 ^{a} ±53.71	NS / 0.012

Mean values with different superscripts in each row indicate a significant difference (P<0.05) based on Tukey's test;
Significance level: * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$, P>0.05=NS, not significant; r^2= coefficient of determination

the highest in T_1 which was higher 53% from T_2 and 12% from T_3 treatment. The SGR of rui was the lowest in T_2 where the water environment was pond. The survival rate was the lowest in T_3. There was no significant difference among the treatments. In view of three treatments, the gross yield was the highest in T_2 treatment and also significantly varied within the treatments.

The growth performance of catla was better both in pond and rice-field ecology. The individual harvesting weight of catla was the highest (398.25 ±23.66 g) in T_1, where stocked carp and mola. The individual harvesting weight was counted 27% variability on growth. And the SGR of catla was higher in T_1 than T_2. At the end of the experiment the survival rate was recorded 14% higher in T_2 than T_1. The survival rate, gross yield and net yield were varied highly significant among the treatments.

The bottom feeder, mrigal is the suitable species in polyculture of rice-field and pond as well. It was affected positively on total production. In rice-field, mrigal was the highest growth in T_1 and the 2nd highest was in T_3 treatment. And also 20% higher SGR of mrigal was in T_1 than in T_2 but the lowest (72%) survival rate was recorded in T_3 treatment. All the growth parameters of mrigal were observed highly significant differences except initial weight among the treatments.

Silver carp initial weight was not varied significantly but highly significant of harvesting weight between the rice-field and pond. The Specific growth rate (2.47% bwd^{-1}) and weight gain (586.75 g) of that species was the highest in T_3 treatment. But in T_2 treatment, the gross yield of silver carp was higher 86% and 73% than T_1 and T_3, respectively. Consisting of all growth parameters in mrigal were varied highly significant except initial weight among the treatments.

Silver barb is the more adaptable in polyculture system of rice-field and pond as well. The individual harvesting weight was higher in T_3 treatment 27% and 21% than in T_2 and T_1, respectively. The survival growth rate was the lowest in T_2 treatment. But the gross yield (139.29 kg ha^{-1}) and net yield (132.12 kg ha^{-1}) were recorded the highest amount in T_3. All the observed growth parameters of silver barb were highly significant differences among the treatments.

Bata is the popular species of marginal farmers of that experimental site. Both the highest initial weight (13.33 g) and harvesting weight (139.33 g) of bata were found in T_1 treatment. But the SGR value was the highest (1.64 % bwd^{-1}) in T_3 and similar in T_1 and T_2 treatment. But the survival rate (72%), gross yield (40.95 kg ha^{-1}) and net yield (36.09 kg ha^{-1}) were the lowest in T_3 treatment. Out of seven growth parameters, SGR and survival rate of bata were not varied significantly among the treatments.

Consisting of self-recruiting species, mola was bred in all ponds and rice-fields during the experimental period. The gross yield and net yield of mola were documented 503.78±33.33 kg ha^{-1} & 448.49±20.52 $kgha^{-1}$ in T_1 and 535.68±37.80 $kgha^{-1}$ & 498.63±37.80 $kgha^{-1}$ in T_2 treatment. And without any stocking, other some small indigenous species were harvested 448.49 $kgha^{-1}$, 395.75 $kgha^{-1}$ and 483.28 $kgha^{-1}$ in T_1, T_2 and T_3, respectively (Table 3).

On the basis of independent sample t-test, only silver carp and other SIS production were not significant between the two rice-fields. The production of rui, catla, mrigal and silver carp were varied significantly but silver barb, bata, mola and other SIS were not significantly differences between the two treatment, T_1 & T_2 (Table 4).

Table 4: Production differentiate of all fishes in case of independent sample t-test among the Treatments

Fish species	T_1 & T_2		T_1 & T_3	
	t-value	level of sig. / r^2	t-value	level of sig. / r^2
Rui	-3.263	** / 0.326	3.263	** / 0.326
Catla	-8.279	*** / 0.757	3.158	** / 0.312
Mrigal	-3.407	** / 0.345	3.949	*** / 0.415
Silver carp	-6.456	** / 0.279	-0.926	NS / 0.037
Silver barb	2.916	NS / 0.022	-1.933	** / 0.153
Bata	0.705	NS /0.022	9.462	*** / 0.803
Mola	-0.633	NS / 0.018	-	-
Other SIS	1.469	NS / 0.089	-0.605	NS / 0.016

The gross yield of all species among the different treatments has been presented graphically in Fig. 6. The total gross yield of silver carp was the highest in T_2 (616.64 kg ha^{-1}) and the lowest of bata was in T_3 (40.95 kg ha^{-1}).

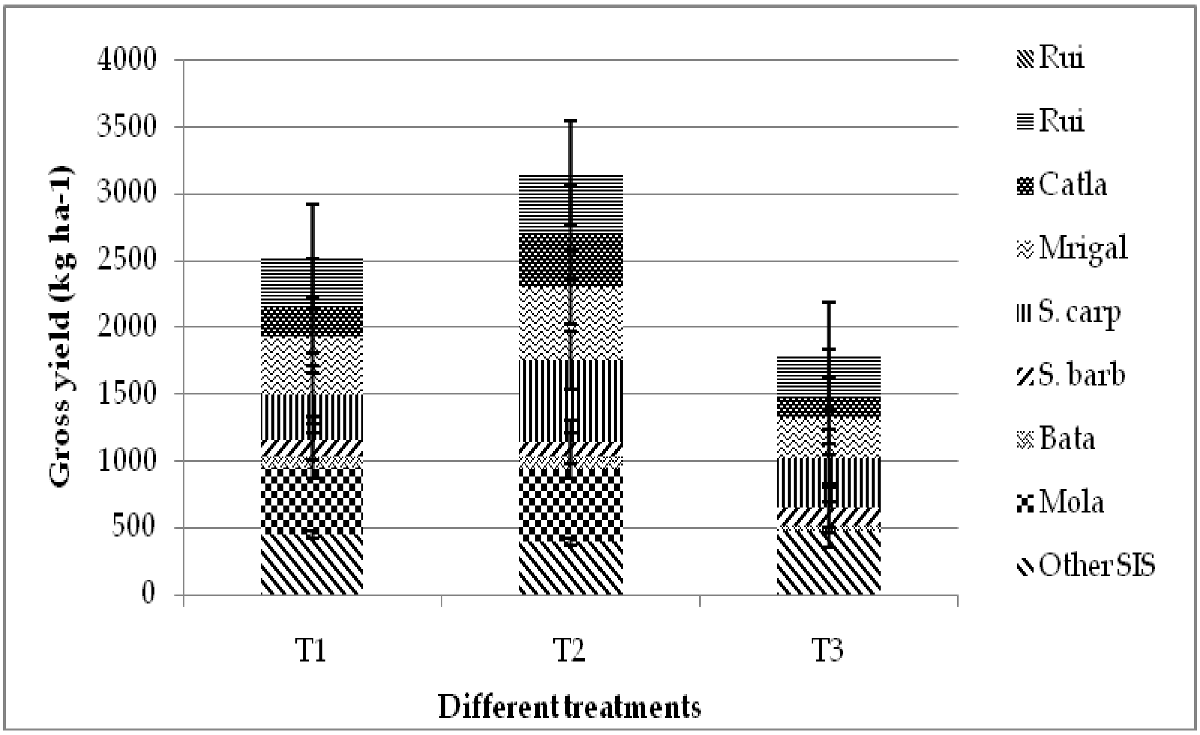

Fig 6: Total gross yield with different species among the treatments

The total gross yield was grouped the following items: carps, mola and other SIS. Considering from that, the yield of all groups has been shown in Fig. 7. The total gross yield of all fishes was recorded 1789.44 kg ha^{-1}, 3157.96kg ha^{-1}, 2525.98 kg ha^{-1} in T_1, T_2, and T_3 respectively.

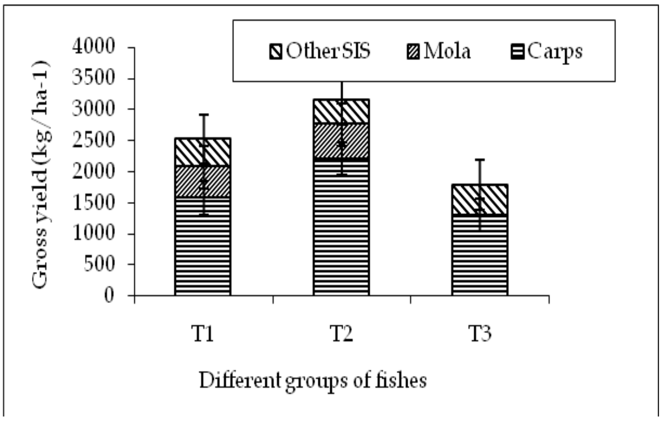

Fig 7: Mean fish yield (±SE) with different groups among the treatment

The total gross yield into group-wise (%) of different treatments are presented in Fig. 8. The total production percentage (%) of carps, mola and other SIS were observed 62, 20 & 18 % in T_1 and 70, 17 & 13 % in T_2. But in without mola treatment covers 73% carps and 27 % other SIS.

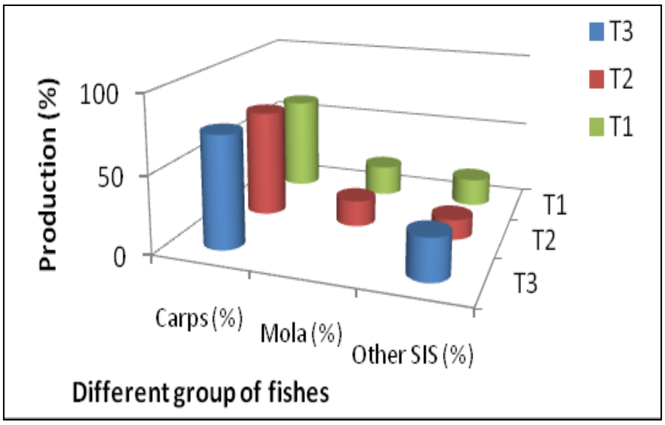

Fig 8: Different groups of fish production (%) among the treatments

Among the all groups were enveloped in income/return. Different groups *i.e.* carps, mola and other SIS were recorded in a Figure 9 from their total income (%). Self-recruitment species, mola plays a vital role which covers 33% in T_1 and 47% in T_2 treatments from the total income of the experiment.

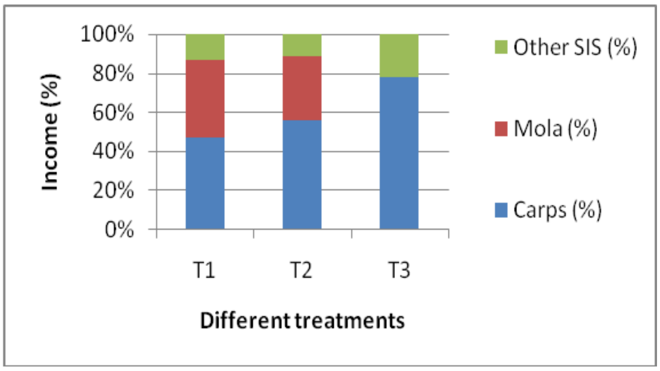

Table 9: Income (%) of different category of fishes among three treatments

The biotechnical managements like selective harvesting of different species especially mola enhanced the total yield as a whole. And also the uses of household consumption have been adjusted with the total harvesting. Considering the total production with all self-recruiting species in rice-fields enhance the value of BCR. Among the three treatments, the value of BCR was the highest (3.43) where mola produced more (Table 5 & Fig. 10).

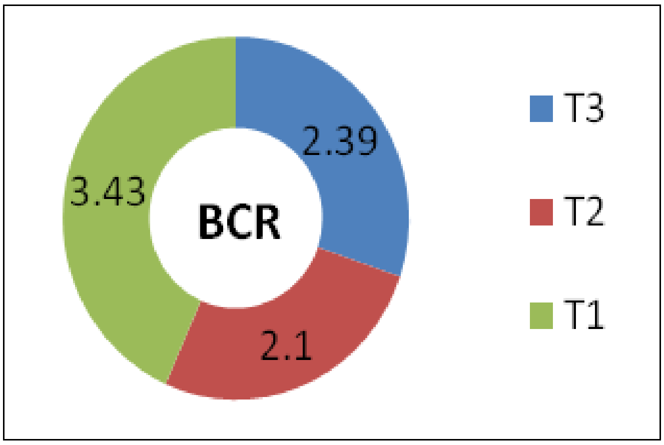

Fig 10: The value of BCR in different treatments of the experiments

Table 5: Comparison of economics parameters among the different treatments based on 1 ha fallow rice-fields

Items	Treatment		
	T_1	T_2	T_3
Financial inputs			
Pond preparation cost			
Embankment repair	15556	44346	29120
Clay removal	-	-	
Lime	1694	1820	2902
Fertilizer (urea & TSP)	1059	1137	1813
Stocking cost			
Carps	6429	9944	8451
Mola	7410	6823	-
Pond management cost			
Fertilizer (urea & TSP)	3176	3411	3880
Lime	-	3009	-
Rice bran	4658	21101	5343
Netting & others	18207	24261	20800
Total cost	62188	115852	72309
Financial returns			
Carps	99618	136160	134484
Mola	86420	81882	-
Other SIS	27446	25663	38275
Total returns	213485	243705	172759
Net benefits	151297	127853	100450
Benefit-cost ratio (BCR)	3.43: 1	2.10: 1	2.39: 1

Currencies are given in Bangladesh Taka

Discussion

Water quality parameters

Temperature

Temperature is an important issue which influences growth and all biological activities of fishes. The observed range of water temperature (19-34 ^{0}C) was more or less similar with the findings were recorded 18.5-33, 18.5-33, and 18-34.10 ^{0}C by Kohinoor (2000) [22], Dewan (1973) [11] and Roy (2004) [35], respectively. The values of temperature were significantly differences among the rice-fields and ponds. Hence, the temperature was contended the entire experiment for growth of craps and self-recruiting species, mola along with breeding.

Transparency

The estimated transparency might be due to application of manure, grazing pressure by fishes during the experiment.

Boyd (1982) [9] commented transparency between 15-40 cm is good for fish production. The water transparency showed variation with sampling dates and it ranged 18-51 cm. Kohinoor (2000) [22] and Roy *et al.* (2002) observed that parameter in their carp-SIS polyculture were 18-58, 19-55 cm, respectively. Those results were almost similar in the present study which indicated the favorable condition for as well.

pH (Hydrogen ion concentration)

Above neutral level or slight alkaline pH is favorable for fish culture. Swingle (1967) [37] reported that acidic pH reduces the growth, metabolism and other physiological activities of fishes. In the present study was observed above neutral level of pH throughout the experimental period in ponds and rice-fields as well. The values of pH varied highly significant among the treatments.

DO

Dissolved oxygen (DO) content is probably the most important water quality parameter in aquaculture. Delayed exposure to low concentration of DO can be detrimental to aquatic life. In the present study, the dissolved oxygen content of water was observed between 2.50-7.30 mgL^{-1}. Kohinoor (2000) [22] & Uddin (1998) [40] reported the range of dissolved oxygen (3.7-6.0 mgL^{-1}) which was close to the present study.

Alkalinity

The total alkalinity levels more than 100 mgL^{-1} should be present in highly productive water bodies (Alikunhi, 1957) [3]. Ophenheimer *et al*. (1978) [32] and Bhowmic & Tripathi (1985) [8] found the total alkalinity range between 64.85 - 85.36 and 19.4 - 92.6 mgL^{-1} in the research ponds in Bangladesh and India, respectively. Amin & Salauddin (2008) [5] was documented the total alkalinity values vary 30-100 mgL^{-1} in the rice fields. The findings of the present study showed similarity with the above researchers. The values of alkalinity varied highly significant among the treatments.

Therefore, the values of different water quality parameters were estimated to be within the acceptable ranges for fish culture under prevailing conditions in and around the experimental sites.

Impact on environmental manipulation

Interfering the water environment through the polyculture composition in rice field and pond. The production performance carps with mola in both two water bodies pond and alternate rice plots were significantly affected. In addition, there are more than 2.83 million ha of seasonal paddy fields (Karim 1978) [19], which are used to grow mainly one crop of boro rice from January to May. For the remaining part of the year, the lands lie fallow and flooded under monsoon water. The carrying capacities of these lands and waters have not been fully utilized yet, but there exists tremendous potential for increasing fish production by integrating aquaculture in these inundated rice fields.

In rotational rice-field, carp and mola were cultivated (RCM) for high yield in T_1 treatment. General stocking density of carps in rice field was half (20/dec.) than the pond (40/dec.) followed by Dutta *et al.* (1979) [13]. Because of the water volume was low in rice-field than the pond. The stocking weight of all Indian major and minor carps was more or less coincided. But that parameter of rui, silver barb and bata were significantly different among the treatments. Within four Indian major carps, rui was occupied the lowest growth rate but the harvesting growth of silver carp was high in T_1. The mean harvesting weight of rohu was found 373 g which was higher than Kunda *et al.* (2009) [24 25] and Ashrafuzzaman (2004). In the rotational system, the mean gross production of rui were recorded 197 to 205 kg ha^{-1} in 120 days culture period which was lower than the present study (Kunda *et al.*, 2009) [24, 25]. Although the SGR of catla was found in the different experiment (Kunda *et al.*, 2008 and Kunda *et al.*, 2009) [23-25] were ranged from 1.88-2.09 (%bw day^{-1}) which was lower the present study. Among the two minor carp bata was the lowest. Usually weight gain of all fishes depend on harvesting weight. The SGR value of silver carp was similar between T_1 and T_2 treatment. Whereas, SGR value of bata was same between the two treatments T_1 and T_2. The survival rate of rui and silver barb were the highest in T_1 among the other treatments. From the all stocked fishes, the survival rate of molas was not recorded because mola bred during the culture period: therefore, the harvesting number was higher than the stocking. The gross yield of all carps except silver carp was higher in T_1 than T_3 rice-field treatment. Kunda *et al.* (2009) [24, 25] documented the gross of production of mola in alternate rice culture system in different trial ranged from 148 – 208 kg ha^{-1} which was lower than the present study. From the independent sample t-test revealed the gross yield of all Indian major carps were significantly varied between rice-field & ponds treatments having carps with mola species (Table 4). Whereas, the net yield were increased in the similar trend in fish species. The net yield of all fish species were varied significantly among the all treatments. In the present study, production of mola contribute one-third of carps but the income only less than 7% of carp. It was possible for the high market value of mola and which also increased the BCR (3.43) from the other treatments.

The ponds were selected for carp-mola polyculture (PCM) in nearby rice-field area. The mean harvesting weight of rohu was found 252 g which is more or less similar to Azim *et al.* (2001) and Ahsan (2013) [2]. And also Ahsan (2013) [2] recorded the net production of rohu was 180 to 372 kg ha^{-1} in 172 days culture period which was lower than the present study. In the study, except catla, the harvesting weight of all fishes was lower in T_2 among the three treatments. Mean harvesting weight of catla in T_2 ranged from 336 g which is comparable to Islam (2005) [18] and Nahid (2006) [31]. But only the SGR of catla was higher in T_2 than rice-field treatments. While the survival rate of all fishes except rui were higher in T_2 than the other two treatments. Within the all carps, catla and bata were no significant difference in case of survival rate among the treatments. The gross yield of all carps were the highest performance in pond except silver barb. The harvesting weight of silver carp was found 285 to 505 g which is higher than Ahmed (2005) [1] who found mean weight ranged from 189.9 to 280.35 g. The increment rate of silver barb also higher in Mekong Delta rice field in Vietnam (Rothius, A. J., 1994) [34]. Among the all carps, silver barb was the highest yield (616.64 kg ha^{-1}). Between two minor carps, gross yield of silver barb was lower in pond than rice field. It takes available grass particles in rice-fields which enhance the growth and production. The gross yield of mola was 6% higher in T_2 treatment. Although the gross yield of other SIS was 11% & 22 % lower in T_2 than in T_1 & T_3 respectively which are comparable to Alim *et al.* (2004) [4]. Different types of small fishes were comparatively using as rice-field it's breeding ground and produce more. Among the all treatments were significantly varied in case of gross yield parameters.

Rice–field is also suitable environment for carps in rotational system. During this experiment, silver carp and silver barb were the highest growth performance in T_3 than T_1 & T_2 and along with same trend in case of weight gain and SGR among the treatments. A major component of the silver barb diet consisted of rice plants and accessible grains. The herbivorous (macrophyte feeding) silver barb is frequently used in Asian ricefish systems, e.g. Thailand (Fedoruk & Leelapatra 1992) [14] and Bangladesh (Dewan 1992) [10]. Not much is known about the feeding behaviour of silver barb in ricefields. However, herbivorous fish are known to cause damage to rice plants (Mathes 1978; Khoo & Tan 1980; Moody 1992) [27, 21, 29]. In that treatment silver carp cannot competent with mola because the absence of mola. Different diversity of phytoplankton were abundant in rotational rice-field. So plankton feeder silver carp increases rapidly. But the survibility of all carps were the lowest in rice-fields with only carps than the other systems. While the survival rate of catla was same amount (%) between the two rotational rice-field systems. Although, the gross yield & net yield of silver barb was the highest and bata was the lowest in T_3 among all treatments. But the gross yield of silver carp and other SIS were not significantly differences between two rice-field systems when tested independent sample t-test (table 5). And also Other SIS production was the highest in that treatment. The gross yields were varied significantly among the all treatments.

In order to meet soaring demand of Bangladeshi people for fish food & nutrition, there is a need for increased fish in ponds and inundated rice field were the greatest potentiality. It is likely that natural fish-food organisms may grow well in an organic matter-rich environment like the fallow rice-fields of the present study containing semi-decomposed rice straw and roots. Rice fields are very productive in terms of both the quantity and the variety of natural food organisms for fish and the energy & nutrients in them can be recycled electively by culturing fish. Rotational culture advantage is that in the next season when the farmers cultivate rice, no fertilizer or very little fertilizer may be required, because excreta of fish deposited in the bottom soil may act as a nutrient source for the rice. It also generate crop diversification program which produce more for nutrient accumulation and alter/reduce the disease susceptible macro & microorganisms in only fish culture followed by only rice culture.

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