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Fish growth, yield and economics of conventional feed and weed based polyculture in ponds

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Abstract

Fish growth, yield and economics of polyculture were evaluated for six months from April to September, 2011 in ponds of Kushtia district, Bangladesh under 4 treatments of feeds and weeds as T_0: rice bran, wheat bran and mustard oilcake; T_1: Azolla; T_2: Grass and T_3: Banana leaf. Each treatment had 3 replications. Mean initial stocking weight of fishes like *Hypophthalmichthyes molitrix, Catla catla, Labeo rohita, Cirrhinus mrigala, Cyprinus carpio, Ctenopharyngodon idella* and *Barbonymus gonionotus* was 62, 64, 57, 54, 63, 65 and 25 g, respectively. Stocking density (11,115 fishes/ha), liming (250 kg/ha), basal fertilization (Cowdung, 1,500 kg/ha; urea, 60 kg/ha; and Triple Super Phosphate, TSP 60 kg/ha) and periodic fertilization (Urea, 2.5 kg/ha/day; and TSP, 2.5 kg/ha/day) were same for all the treatments. Water quality parameters (water temperature, transparency, dissolved oxygen, pH, alkalinity and free carbon dioxide) were monitored fortnightly and fish growth parameters (weight gain and Specific Growth Rate, SGR) were monitored monthly. Treatments did not vary significantly for the mean water quality parameters. Treatment T_0 varied more significantly ($P<0.05$) for the mean final weight, weight gain, SGR, survival rate and yield for almost all the species except *C. idella* and *B. gonionotus*. Significantly highest CBR was recorded with treatment T_1.

Keywords: Feed, weed, growth, yield, economics, fish polyculture

INTRODUCTION

Feeds are the major expenditure in any fish culture operation (Mukhopadhyay and Jena 1999) which contributes to cost increase per unit production (New and Csavas 1993). The weed based system refers to the use of some inputs from plant sources e.g., weeds or grasses or leaves or macrophytes like duckweeds, *Azolla* etc. as feed in fish production. These inputs are consumed first as feed by herbivorous fish and subsequently a part of the semi digested fecal matter of the macrophytes feeding fishes are consumed by the other fishes and the remaining part will be recycled in food chain as nutrients for primary production, thus they have potentiality to increase the total fish production of aquaculture system (Grover *et al*. 2000). Okeyo (1989) listed a number of aquatic macrophytes (*Azolla pinnata*, *Chara* sp., *Eichhornia crassipes*, *Ipomoea aquatica*, *Lemna minor*, *Nymphae* sp., *Trapa natans*, *Wolffia arrhiza*, *Lactuca sativa*, *Typha latifolia*) as potential source of nutrients which are directly used as food components by a number of herbivorous fish. *Azolla pinnata* acts as direct food by some macrophytophagous fish (Cassani 1981). Fresh duckweed (and also the dried meal) is suited to intensive production of herbivorous fish (Gaiger *et al.* 1984) and duckweed is converted efficiently to live weight gain by carp and tilapia (Hassan and Edwards 1992). Carp polyculture is a popular technology in Bangladesh and carp alone contributes about 35% of total fish production (DoF 2015). Weed as an alternative to the conventional feed like rice bran, wheat bran and mustard oilcake can be made available for carp polyculture at minimum or no cost for the poor farmers in Bangladesh. Researches carried out on the application of weed have so far been centered on the waste water treatment (Oron 1994; Alaerts *et al*. 1996). With a few exception of some efforts on duck weed based aquaculture (Azim and Wahab 2003; Uddin *et al.* 2007), no comprehensive studies are done to date for the promotion of low cost and environment friendly weed based aquaculture in Bangladesh. Therefore, the present study aimed at evaluating the fish growth, yield and economics of polyculture under conventional feed and weed fed ponds. The specific objectives included in this study were to monitor the water quality parameters; to evaluate the fish growth and yield; to evaluate the economics of fish farming under feed and weed based systems; and thereby to recommend low cost aquaculture technology for polyculture ponds.

METHODOLOGY

Location and duration of study: The study was conducted for a period of six months from April to September, 2011 at Alampur village of Sadar Upazila (23^{o}42′ and 23^{o}59′ North latitude; 88^{o}55′ and 89^{o}04′ East longitude) under Kushtia district, Bangladesh. A total of 12 ponds (average water area of 0.18±0.01 ha and depth of 1.9±0.08 m) were selected for the present study. All the ponds were rain-fed and well exposed to sunlight.

Experimental structure: The experiment was designed under Randomized Completely Block Design (RCBD) with four different treatments of fish feeds, each with three replications (Table 1). Fish stocking density (individuals/ha) (Silver carp, *Hypophthalmichthyes molitrix*: 2223; Catla, *Catla catla*: 741; Rohu, *Labeo rohita*: 2470; Mrigal, *Cirrhinus mrigala*: 1235; Carpio, *Cyprinus carpio*: 741; Grass carp, *Ctenopharyngodon idella*: 1235 and Thai punti, *Barbonymus gonionotus*: 2470; total: 11,115) was same for all the treatments. Mean initial stocking weight of *H. molitrix*, *C. catla*, *L. rohita*, *C. mrigala*, *C. carpio*, *C. idella* and *B. gonionotus* were 62, 64, 57, 54, 63, 65 and 25 g, respectively. Variation of major nutrient contents (protein, lipid and carbohydrate) of the feed items used for this experiment is shown in Table 2. Samples for both conventional and non-conventional feed items were collected once in a month for nutrient analysis during the experimental period. Protein, lipid and carbohydrate of the collected samples were determined by the micro-kjeldahl method (Rangama 1979), Bligh and Dyer (1959) method and Anthrone method (Boel *et al*. 1988), respectively.

Table 1: Experimental layout

Parameters	***Treatments***											
	T_0: rice bran, wheat bran and mustard oilcake fed ponds			***T_1: Azolla (Azolla pinnata) fed ponds***			***T_2: Grass (Cynodon dactylon) fed ponds***			***T_3: Banana (Musa acuminata) leaf fed ponds***		
Pond area (ha)	0.16	0.18	0.22	0.22	0.14	0.16	0.12	0.16	0.22	0.18	0.20	0.18
Pond depth (m)	1.7	1.9	2.3	2.1	1.6	1.7	1.5	1.7	2.3	2.3	1.9	1.8
Total fish stocked	1778	2001	2445	2445	1556	1778	1334	1778	2445	2001	2223	2001

Table 2: Nutrient (protein, lipid and carbohydrate) contents under different feed items

Nutrients	***Feed items under different treatments***					
	Rice bran (T_0)	***Wheat bran (T_0)***	***Mustard oilcake (T_0)***	***Azolla (T_1)***	***Grass (T_2)***	***Banana leaf (T_3)***
Protein (%)	14.40±0.32	17.13±0.07	30.53±0.40	18.58±0.09	7.26±0.18	6.18±0.13
Lipid (%)	10.41±0.31	6.69±0.30	13.33±0.10	3.19±0.10	6.31±0.13	3.06±0.09
Carbohydrate (%)	44.09±0.67	66.12±0.47	32.95±0.29	50.21±0.54	46.36±0.16	48.50±0.51

Pond management: Aquatic weeds were removed from all the ponds manually. Predatory fish and other unwanted species were removed through repeated netting. Liming was done for all the experimental ponds at a rate of 250 kg/ha before 7 days of basal fertilization. Basal fertilization (Cowdung, 1500 kg/ha; urea, 60 kg/ha and Triple Super Phosphate, TSP 60 kg/ha) and periodic fertilization (Urea, 2.5 kg/ha/day; and TSP, 2.5 kg/ha/day) were also same for all the treatments. Fish seeds were collected from a local government fish farm and stocking was done at early morning after 7 days of basal fertilization. In ponds under treatment T_0 commonly available conventional feed ingredients such as rice bran (30%), wheat bran (30%) and oilcake (40%) were used as supplementary feed daily at the rate of 4% of fish body weight for the first 2 months (April and May), 3% for the next 2 months (June and July) and finally, 2% for the last 2 months (August and September) of culture period. Fishes were fed twice a day at 09:00 to 10:00 AM and at 03:00 to 04:00 PM with 50% of the ration allocated at each time. *Azolla*, grass and banana leaf for ponds under treatments T_1, T_2 and T_3, respectively were supplied as supplementary feed daily at the rate of 100% of the body weight of herbivorous fishes (*C. idella* and *B. gonionotus*). One tenth area for each of the research ponds under treatment T_1 was used as Azolla bank according to Grover *et al*. (2000). *Azolla* was supplied from *Azolla* bank, whereas grass and banana leaves were collected locally and chopped into very small pieces during application.

Water quality monitoring: Some important water quality parameters of the experimental ponds such as water temperature, transparency, dissolved oxygen (DO), pH, alkalinity and free carbon dioxide (CO_2) were monitored fortnightly between 10:00 AM to 11:00 AM for the present study. Water temperature was recorded with the help of a Celsius thermometer at 20 to 30 cm depth of water. Transparency was measured by a Secchi disk. DO, pH, alkalinity and free CO_2 were determined by the help of a HACH kit (FF-2, USA).

Fish growth monitoring: At least 10% of the stocked fishes from each species in each pond was caught during monthly sampling with a cast net. On each sampling day, individual fish from each pond was weighed and measured to determine the fish growth and to adjust the feed ration. Growth and yield of fishes were calculated as follows:

Final weight (g) = Weight of fish at harvest (g)

Weight gain (g) = Mean final weight (g) - Mean initial weight (g)

Specific Growth Rate (SGR, % bwd^{-1}) = [L_n (final weight) – L_n (initial weight)] / culture period (days) $\times$ 100 (Brown 1957)

$$\text{Survival rate (\%)} = \frac{\text{Number of fish harvested}}{\text{Number of fish stocked}} \times 100$$

Fish yield (kg/ha/6 months) = Fish biomass at harvest – Fish biomass at stock

Economics of fish polyculture: Simple cost-benefit analysis was done to explore the economics of feed and weed based polyculture of fishes under different treatments. At the end of the study, all the fishes were sold in a local market. The prices of inputs and fish corresponded to the market prices in Bangladesh in 2011 and were expressed in Bangladesh currency (Taka), BDT (1 US$=78 BDT). Data on both fixed and variable costs were recorded to determine the total cost (BDT/ha). Total return determined from the market price from fish sale was expressed as BDT/ha. The net benefit and cost benefit ratio (CBR) were calculated as follows:

Net benefit (BDT/ha) = Total return (BDT/ha) – Total cost (investment) (BDT/ha)

$$\text{CBR} = \frac{\text{Net benefit}}{\text{Total investment}} \text{ (Shang 1990)}$$

Data analysis: Data on water quality parameters, fish growth and yield and economics of polyculture under different treatments were subjected to one way ANOVA (Analysis of Variance) using computer software SPSS (Statistical Package for Social Science, version-15). All data were expressed as mean±standard error (SE). The mean values were also compared to see the significant difference from the Duncan Multiple Range Test (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Water quality: The mean values of water quality parameters in different treatments are presented in Table 3. During study period the mean values of water temperature varied from 31.19±0.20 to 31.29±0.24 °C. Ferdoushi *et al*. (2008) reported water temperature as 29.30±2.63 to 29.60±2.97 °C while working on the effects of two aquatic floating macrophytes (*Lemna* and *Azolla*) in fish pond. Water temperature of 25 to 32 °C is considered suitable for fish culture (Boyd and Zimmermann 2000). The mean value of water transparency varied from 32.28±0.3 (T_2) 2 to 32.83±0.40 (T_1) cm. Azim and Wahab (2003) found the transparency value as 36.2 cm in weed based carp polyculture pond. Boyd (1982) recommended the transparency between 25 to 40 cm as appropriate for fish culture. Mean DO values were found as 5.33±0.09 (T_3) to 5.51±0.11 (T_1) mg/l. More or less similar result (4.15 mg/l) was made by Thy *et al*. (2004) in effluent plus water spinach research pond. Azim and Wahab (2003) recorded DO value ranging from 4.1 to 5.25 mg/l in duckweed based carp polyculture pond. The suitable range of dissolved oxygen is 5 to 8 mg/l for fish culture (Boyd 1998). In this experiment, mean value of pH varied from 7.18±0.03 (T_3) to 7.38±0.05 (T_1) which indicated that ponds were within the suitable range for feed and weed based carp polyculture system. According to Swingle (1967), pH of 6.5 to 9.0 is suitable for fish culture. The recorded mean total alkalinity varied from 113.28±0.85 (T_1) to 114.36±0.72 (T_0) mg/l. Mitra *et al*. (1978) found alkalinity as 100.00 to 162.00 mg/l in carp polyculture pond. Boyd (1982) advocated that the total alkalinity should be more than 20 mg/l in fertilized pond as production increases with the increase in total alkalinity. Mairs (1996) also stated that the total alkalinity of 40.0 mg/l or more to be productive than water bodies with lower alkalinity. Mean value of free CO_2 varied from 2.82±0.07 (T_1) to 3.03±0.07 (T_0) mg/l. The suitable range of free CO_2 for fish culture is ranged from 1.0 to 10.0 mg/l (Boyd 1998). Wurts and Durbrow (1992) reported the desirable range of CO_2 as 1 to 2 mg/l for pond aquaculture. No significant difference was found among the treatments for mean values of water quality parameters. Findings also indicated that water quality parameters were found within suitable range for aquaculture.

Table 3: Water quality parameters in different treatments during study period

Parameters	***Treatments***			
	T_0	***T_1***	***T_2***	***T_3***
Water temperature (°C)	31.29± 0.24^a	31.20± 0.20^a	31.24± 0.21^a	31.19± 0.20^a
Transparency (cm)	32.34± 0.25^a	32.83± 0.40^a	32.28± 0.32^a	32.44± 0.24^a
DO (mg/l)	5.39± 0.12^a	5.51± 0.11^a	5.34± 0.12^a	5.33± 0.09^a
pH	7.22± 0.03^a	7.38± 0.05^a	7.25± 0.05^a	7.18± 0.03^a
Alkalinity (mg/l)	114.58± 0.67^a	113.61± 0.74^a	114.05± 0.87^a	113.94± 0.80^a
Free CO_2 (mg/l)	3.03± 0.07^a	2.82± 0.07^a	3.00± 0.07^a	3.02± 0.06^a

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

Fish growth: Mean values of growth parameters of fishes under different treatments are shown in Table 4. After 6 months rearing, the highest final weight was observed as 678.67±12.57 g in *C. catla* and that of lowest was in *B. gonionotus* as 115.67±2.60 g. Such variation in final weight was mainly due to the variation in the stocking size of the species. However, significantly highest final weight of *C. idella* (620.33±18.02 g) and *B. gonionotus* (229.67±2.67 g) with treatment T_1 indicated the availability of suitable feed for the herbivorous fishes with that treatment. Majhi *et al.* (2006) reported the final weight as 270.34 g of *C. idella* fed with *Azolla* in 150 days culture period at a stocking density of 0.75 fish/m^2 and initial size of 23.50±5.0 g.

Mean monthly weight gain (g) significantly varied with *H. molitrix* from 45.72±4.66 g (T_3) to 95.78±5.56g (T_0), *C. catla* from 49.06±5.28 g (T_3) to 102.45±14.41g (T_0), *L. rohita* from 33.39±3.30 g (T_2) to 74.17±6.55g (T_0), *C. mrigala* from 33.78±3.68 g (T_3) to 74.33±5.59 g (T_0), *C. carpio* from 46.00±4.51 g (T_3) to 80.61±4.99 g (T_0), *C. idella* from 72.84±5.13 g (T_3) to 95.17±6.99 g (T_1) and *B. gonionotus* from 15.11±1.95 g (T_3) to 34.95±4.53 g (T_1). Monthly weight gain of fishes found during the study was more or less similar to the findings found under usual carp polyculture system. Azad *et al*. (2004) reported the weight gain of *H. molitrix* as 72.87 g and *C. mrigala* as 70.42 g while working with carp polyculture using low cost input.

In the present study, comparatively higher SGR (%, bwd^{-1}) obtained with *C. idella* (1.31±0.31) and *B. gonionotus* (1.05±0.25) in treatment T_1 clearly indicated that growth of herbivorous fishes was well supported by *Azolla* fed pond. Majhi *et al*. (2006) recorded SGR value of *C. idella* as 1.65%, bwd^{-1} in *Azolla* fed fish pond. Kohinoor *et al.* (1999) observed the SGR value of Thai punti as 1.33 to 1.35 %, bwd^{-1} in polyculture with carps using low-cost feed.

The survival rate (%) varied with *H. molitrix* from 81.33±1.20 (T_2) to 84.33±2.03% (T_0), *C. catla* from 75.33±1.59 (T_2) to 81.00±1.73% (T_0), *L. rohita* from 77.67±1.45 (T_3) to 81.33±0.88% (T_0), *C. mrigala* from 67.50±1.44 (T_2) to 80.33±2.91% (T_0), *C. carpio* from 78.00±1.73% (T_2) to 86.33±2.40% (T_0), *C. idella* from 73.00±1.15 (T_0) to 83.00±1.15% (T_1) and *B. gonionotus* from 70.33±1.45 (T_0) to 78.67±0.67% (T_1). Das *et al*. (1982) reported the survival rate (%) of rohu, catla, mrigal and silver carp as 88.64 to 90.18, 85.81 to 90.06, 84.93 to 91.36 and 92.35 to 96.96, respectively in polyculture of carps. Roy *et al*. (2002) reported the survival rate (%) of grass carp, rohu, catla and mrigal as 76.6, 87.8, 84.0 and 88.6, respectively in carp polyculture pond. Considering all the species, survival rate in the present study was found more or similar to Wahab *et al.* (1995) who recorded the survival rate of fishes as about 80% in carp polyculture pond.

Fish yield

Treatment T_0 varied more significantly for all the species except the herbivorous fishes (*C. idella* and *B. gonionotus*) (Table 5). No significant difference in yield was found between the treatments T_2 and T_3 for all the species. Highest yield of *C. idella* (603.67±71.64 kg/ha/6months) and *B. gonionotus* (375.67±41.34 kg/ha/6months) with treatment T_1 clearly indicated the smooth supply of suitable feed like Azolla for the herbivorous fishes with that treatment. Considering all the species, total fish yield significantly varied from 2541.00 (T_3) to 4403.51 (T_0) kg/ha/6 months (Table 5). Among the treatments with weed baed systems, significantly highest total yield (3675.33±0.58 kg/ha/6 months) was found with treatment T_1 (Azolla fed) than other two treatments like T_2 (grass fed) and T_3 (banana leaf fed). Therefore, present findings indicated that variation in nutrient contents of the feed items under different treatments (Table 1) had significant effect on the total fish yield.

Table 4: Growth of fishes under different treatments

Species	*Treatments*	*Final weight (g)*	*Weight gain (g/month)*	*SGR (%, bwd^{-1})*	*Survival rate (%)*
H. molitrix	T_0	636.67±5.61^{a}	95.78±5.56^{a}	1.29±0.41^{a}	84.33±2.03^{a}
	T_1	487.67±30.21^{b}	70.94±4.17^{b}	1.14±0.31^{a}	82.67±2.60^{a}
	T_2	349.00±4.04^{c}	47.83±3.96^{c}	0.96±0.23^{b}	81.33±1.20^{a}
	T_3	336.33±2.03^{c}	45.72±4.66^{c}	0.94±0.21^{b}	82.67±1.20^{a}
C. catla	T_0	678.67±12.57^{a}	102.45±14.41^{a}	1.31±0.24^{a}	81.00±1.73^{a}
	T_1	499.00±26.10^{b}	72.50±5.46^{b}	1.14±0.32^{a}	79.33±2.33^{a}
	T_2	364.33±2.91^{c}	50.06±5.24^{b}	0.97±0.26^{b}	75.33±1.59^{b}
	T_3	358.33±4.41^{c}	49.06±5.28^{b}	0.96±0.24^{b}	75.33±2.03^{ab}
L. rohita	T_0	502.00±2.08^{a}	74.17±6.55^{a}	1.21±0.38^{a}	81.33±0.88^{a}
	T_1	318.00±16.29^{b}	43.50±5.75^{b}	0.95±0.26^{b}	79.33±2.33^{a}
	T_2	257.33±5.04^{c}	33.39±3.30^{b}	0.84±0.18^{b}	78.00±1.73^{a}
	T_3	259.67±3.48^{c}	33.78±2.70^{b}	0.84±0.16^{b}	77.67±1.45^{a}
C. mrigala	T_0	500.00±7.23^{a}	74.33±5.59^{a}	1.24±0.38^{a}	80.33±2.91^{a}
	T_1	358.67±36.86^{b}	50.78±3.36^{b}	1.05±0.25^{ab}	74.50±3.91^{ab}
	T_2	263.67±6.06^{c}	34.94±2.97^{c}	0.88±0.15^{b}	67.50±1.44^{b}
	T_3	256.67±1.76^{c}	33.78±3.68^{c}	0.87±0.15^{b}	68.50±0.76^{b}
C. carpio	T_0	546.67±8.69^{a}	80.61±4.99^{a}	1.20±0.34^{a}	86.33±2.40^{a}
	T_1	450.00±37.63^{b}	64.50±4.26^{b}	1.09±0.28^{ab}	79.00±3.06^{b}
	T_2	353.00±4.73^{c}	48.33±3.60^{c}	0.96±0.22^{b}	78.00±1.73^{b}
	T_3	339.00±3.79^{c}	46.00±4.51^{c}	0.93±0.22^{b}	78.33±0.88^{b}
C. idella	T_0	575.00±68.46^{b}	82.39±6.10^{ab}	1.03±0.23^{b}	73.00±1.15^{b}
	T_1	620.33±18.02^{a}	95.17±6.99^{a}	1.31±0.31^{a}	83.00±1.15^{a}
	T_2	505.67±5.78^{b}	73.44±5.57^{b}	1.14±0.33^{b}	80.00±6.56^{a}
	T_3	502.00±4.16^{b}	72.84±5.13^{b}	1.10±0.32^{b}	81.33±1.76^{a}
B. gonionotus	T_0	190.33±20.96^{b}	26.72±2.49^{a}	0.93±0.21^{ab}	70.33±1.45^{b}
	T_1	229.67±2.67^{a}	34.95±4.53^{a}	1.05±0.25^{a}	78.67±0.67^{a}
	T_2	116.33±4.33^{c}	15.22±2.78^{b}	0.86±0.28^{b}	74.17±3.63^{a}
	T_3	115.67±2.60^{c}	15.11±1.95^{b}	0.85±0.21^{b}	76.33±1.45^{a}

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

Uddin *et al.* (1994) found a gross yield of 3,415 kg/ha/yr from polyculture of carps with Thai punti. Mahmud (1998) reported a gross yield of 1713.4 kg/ha/120 days in a four species composite culture of major carps including Thai punti through the application of fertilizer and supplementary feed comprising of rice bran (60%) and mustard oil cake (40%) daily at the rate of 3% of fish biomass and duckweed (*Lemna minor*) at the rate of 10% of the body weight of thai punti. Das *et al*. (1982) reported a gross yield of 2102.50 to 4361.43 kg/ha/year in polyculture of major carps with the application of fertilizer and supplementary feed consisting of rice bran (75%) and mustard oil cake (25%). Azim and Wahab (2003) also recorded a total yield of 2020 kg/ha/4 months in duckweed based system. Therefore, in most cases, yield of the present study was more or less similar to the aforesaid scientists working on carp polyculture under feed and weed based systems. In spite of having differences in nutrient contents between conventional feed and plant sourced feeds, a moderate fish yield obtained with treatment T_1 during the present study indicated that Azolla was found potential to increase the yield of herbivorous fishes and thereby to increase the total fish yield. Almost similar assumption was also made by Grover *et al*. (2000) for low cost environment friendly aquaculture.

Economics of fish polyculture: During study period total cost, return, net benefit and CBR significantly varied from 123430.50±0.00 (T_1, T_2, T_3) to 235,930.50±0.00 (T_0) BDT/ha/6 months, 235,068.40±1965.31 (T_3) to 418,376.85±5125.59 BDT/ha/6 months (T_0), 111,639.90±2056.87 (T_3) to 206,744.85±3221.73 (T_1) BDT/ha/6 months and 0.77±0.02 (T_0) to 1.67±0.18 (T_1), respectively (Table 6 and Fig. 1). Abdelghany and Ahmad (2002) reported the total cost (US$/ha) as 2759.00

(215202.00 BDT/ha) and return from fish sale (US$/ha) as 3968.26 (309524.28 BDT/ha) while working on carp polyculture in pond. Highest total cost in treatment T_0 was due to the high feed cost (47.68% of the total cost) whereas highest net benefit and CBR in treatment T_1 was due to obtaining moderate total fish yield through the increase in yield of herbivorous fishes at almost no feed cost involvement. Therefore, present findings proved Azolla based fish farming as a low cost environment friendly technique. Almost similar assumption was made by Shanmugasundaram and Balusamy (1993) while working on Azolla based fish farming in rice field.

Table 5: Yield (kg/ha/6 months) of fishes under different treatments

Species	***Treatments***			
	T_0	***T_1***	***T_2***	***T_3***
H. molitrix	1250.00±14.43^{a} (28.39%)	953.33±59.27^{b} (25.94%)	663.67±6.12^{c} (25.59%)	636.00±3.79^{c} (25.03%)
C. catla	426.33±8.41^{a} (9.68%)	295.67±15.38^{b} (10.86%)	190.00±2.31^{c} (7.33%)	186.67±2.03^{c} (7.35%)
L. rohita	992.00±4.16^{a} (20.26%)	628.33±32.31^{b} (17.10%)	479.33±9.24^{c} (18.48%)	481.33±6.39^{c} (18.94%)
C. cirrhosus	555.00±7.81^{a} (12.60%)	398.33±40.92^{b} (10.84%)	278.67±4.98^{c} (10.74%)	269.67±1.76^{c} (10.61%)
C. carpio	385.00±6.03^{a} (8.74%)	317.00±26.66^{b} (8.63%)	235.33±2.96^{c} (9.07%)	226.00±2.65^{c} (8.89%)
C. idella	566.10±23.36^{b} (12.86%)	603.67±71.64^{a} (16.42%)	531.00±6.11^{b} (20.47%)	527.00±4.16^{b} (20.74%)
B. gonionotus	329.08±5.37^{b} (7.47%)	375.67±41.34^{a} (10.22%)	215.67±8.09^{c} (8.32%)	214.33±4.63^{c} (8.43%)
Total yield	4403.51±0.88^{a}	3675.33±0.58^{b}	2593.67±0.11^{c}	2541.00±0.67^{d}

Figures bearing common letter(s) in a row as superscript do not differ significantly (P <0.05); % contribution by individual species to total fish yield in parentheses.

Table 6: Economics of fish polyculture under different treatments during study period

Variables	***Treatments***			
	T_0	***T_1***	***T_2***	***T_3***
Lease value (BDT/ha)	40000.00±0.00^{a} (16.95%)	40000.00±0.00^{a} (32.41%)	40000.00±0.00^{a} (32.41%)	40000.00±0.00^{a} (32.41%)
Pond preparation cost (BDT/ha)	10550.00±0.00^{a} (4.47%)	10550.00±0.00^{a} (8.55%)	10550.00±0.00^{a} (8.55%)	10550.00±0.00^{a} (8.55%)
Lime and fertilizer cost (BDT/ha)	25400.00±0.00^{a} (10.77%)	25400.00±0.00^{a} (20.58%)	25400.00±0.00^{a} (20.58%)	25400.00±0.00^{a} (20.58%)
Fish seed cost (BDT/ha)	32480.50±0.00^{a} (13.77%)	32480.50±0.00^{a} (26.31%)	32480.50±0.00^{a} (26.31%)	32480.50±0.00^{a} (26.31%)
Feed cost (BDT/ha)	112500.00±0.00^{a} (47.68%)	0.00±0.00^{b} (0.00%)	0.00±0.00^{b} (0.00%)	0.00±0.00^{b} (0.00%)
Harvesting cost (BDT/ha)	15000.00±0.00^{a} (6.36%)	15000.00±0.00^{a} (12.15%)	15000.00±0.00^{a} (12.15%)	15000.00±0.00^{a} (12.15%)
Total cost (BDT/ha)	235930.50±0.00^{a}	123430.50±0.00^{b}	123430.50±0.00^{b}	123430.50±0.00^{b}
Return (BDT/ha)	418376.85±5125.59^{a}	330175.35±2155.32^{b}	239526.95±2335.84^{c}	235068.40±1965.31^{c}
Net benefit (BDT/ha)	182446.35±3265.00^{b}	206744.85±3221.73^{a}	116096.45±3554.84^{c}	111639.90±2056.87^{c}
CBR	0.77±0.02^{b}	1.67±0.18^{a}	0.94±0.03^{ab}	0.90±0.02^{ab}

Figures bearing common letter(s) in a row as superscript do not differ significantly (P <0.05); % of total cost in parentheses

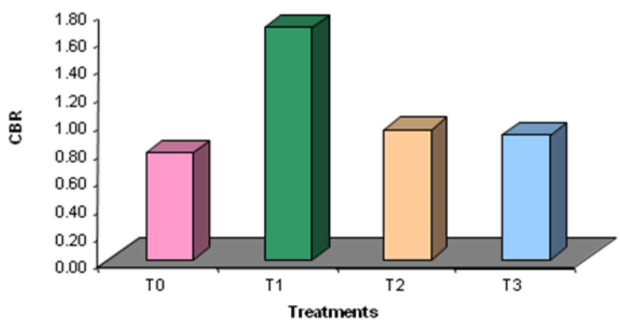

Figure 1: CBR of fish polyculture under different treatments

CONCLUSION

Considering the water quality, fish production and economic viability, it can be concluded that treatment T_1 (*Azolla* based fish polyculture) is more profitable than other treatments. Present study identified *Azolla* based fish farming as a potential low cost aquaculture. On the other hand, the major limitation of this study was with using only one stocking density for all treatments. Therefore, possibilities of finding maximum fish production under *Azolla* based fish farming was not explored well in terms of suitable stocking density. So, it is recommended that optimization of stocking density for

Azolla based carp polyculture in ponds should be explored as further research step.

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