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Production and economic return in pangasiid catfish (*Pangasius hypophthalmus*) monoculture and polyculture with silver carp (*Hypophthalmichthys molitrix*) in farmers' ponds

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Abstract

The production of fish and net economic return in pangasiid catfish (*Pangasius hypophthalmus*) monoculture and polyculture with silver carp (*Hypophthalmichthys molitrix*) in farmers' ponds were assessed. The experiment was arranged in three treatments each with three replications. The ponds were stocked with 30,000 fishes per hectare. In treatment 1 (T_1) pangasiid catfish only, in treatment 2 (T_2) pangasiid catfish and silver carp at the ratio of 1:1, and in treatment 3 (T_3) pangasiid catfish and silver carp at the ratio of 2:1 were stocked. At harvest, production of fish was found significantly ($p<0.05$) different among the treatments, highest in T_1 and lowest in T_2. Though the total biomass production and total economic return was significantly highest in T_1 than in T_2 and T_3, the net economic return was lowest because of the required highest input costs especially for supplemental feed and fingerlings, resulted the highest cost per unit yield (CPY in Tk/kg) in T_1. Highest cost for supplemental feed required in T_1 was due to highest quantity of feed required for the highest number of pangasiid catfish stocked in that treatment. The findings of the present study suggest that though monoculture of pangasiid catfish give higher fish biomass production but polyculture with silver carp is environmentally good and economically profitable.

Key words : Pangasiid catfish, Silver carp, Polyculture, Economic return

Introduction

Aquaculture systems are highly diverse by country and economic importance. Monoculture and polyculture are most common aquaculture systems used for fish production in many countries of the Southeast Asia. Generally in intensive aquaculture system single species of fish or shrimp are raised at high stocking densities and in semi-intensive and extensive culture systems multi species, in some cases single species, are raised in comparatively less stocking densities. In areas where land and water are limited for fish culture and the market demand for the fish is high, intensive monoculture systems has been recommended (Sin and Chiu 1983) and found to be economically viable (Liao and Chen 1983, Rangaswami 1988). However, polyculture efficiently utilize the production potential of the pond (Lin 1982, Chang 1987, Milstein 1992), and the fish species accounting for the world's highest farmed production are grown in polyculture (Lin 1982, Chang 1989).

The pangasiid catfish (*Pangasius hypophthalmus*) is one of the fast-growing and popular fish species in some Asian countries. The fish is extensively cultured by commercial fish farmers in various countries of Asia. In Bangladesh, this exotic species is commonly cultured as a single species since its introduction. In this culture system large quantity of supplemental feed is used, and the pond water receives high quantity of inorganic nutrients from the microbial decomposition of unused fish feed and metabolic wastes. These nutrients favour the excessive production of phytoplankton in pond water that can support additional number of planktivorous fishes without further feed or management cost. But in practical, they remain unutilized and form algal blooms which in turn cause many unexpected problems such as decline in dissolved oxygen, reduced fish growth and off-flavour in pangasiid catfish flesh. Such problems in monoculture of pangasiid catfish could be avoided by using a polyculture approach. Silver carp are generally considered as planktivorous fish (Cremer and Smitherman 1980, Spataru *et al.* 1983). This planktivorous fish species could be cultured together with pangasiid catfish for the management of phytoplankton. Pangasiid catfish and planktivorous silver carp polyculture can improve the water quality by grazing down the phytoplankton by the latter species and enhance the growth of the former species. Fish biomass production and economic return from culture of any species are always considered by the farmers in allocation of resources. Aquatic environmental deterioration and degradation of fish quality in intensive monoculture are affecting the farm economics and profitability of pangasiid catfish farming. To answer these problems, the present study was carried out to assess the production of fishes and economic return in pangasiid catfish monoculture and polyculture with silver carp.

Materials and methods

The experiment was carried out in farmers' ponds at the village Digharkanda under Sadar Upazila of Mymensingh district for a period of 14 weeks during May to August 2002. Nine selected ponds were owned by nine different farmers. The ponds were 5-10 years old and almost similar in size (0.020-0.022 ha). Before start of the experiment, previously stocked fishes were removed from the ponds by repeated netting and then the ponds were treated with lime (CaO) at the rate of 250 kg/ha ten days prior to the stocking of fish fingerlings.

The experiment was conducted in randomized complete block design (RCBD) with three treatments, each with three replications. Each three nearby ponds was considered to be situated in the same block. In all treatments fishes were stocked at the rate of 30000 fishes per hectare. In treatment 1 (T_1) pangasiid catfish only, in treatment 2 (T_2) pangasiid catfish and silver carp at the ratio of 1:1, and in treatment 3 (T_3) pangasiid catfish and silver carp at the ratio of 2:1 were stocked. Same aged and sized fingerlings of pangasiid catfish (21.01-21.67g) and silver carp (4.90-4.93g) were bought from a local vendor and stocked into the experimental ponds. A commercial pelleted feed (Quality

Fish Feed Ltd., Bangladesh) containing 28% crude protein and 6% lipid was fed to pangasiid catfish at the rate of 8% of the body weight per day during the first six weeks, 6% during the second six weeks and 4% thereafter. The feed was given twice daily, one half in the morning (0900 to 0930 h) and the other half in the evening (1700 to 1730 h). The amount of feed given was adjusted biweekly according to the weight gain of the fish.

The pond environmental parameters such as surface water temperature, water depth, transparency, dissolved oxygen, pH, total alkalinity, nitrate-nitrogen (NO_3-N), phosphate-phosphorus (PO_4-P) and chlorophyll-*a* were routinely measured between 9.00 - 10.00 h during each sampling day. Temperature, water depth, transparency, dissolved oxygen and pH was measured weekly using a Celsius thermometer, a graduated pole, a secchi-disk, a portable waterproof dissolved oxygen meter (HI 9142, Hanna Instruments, Portugal) and a portable pH meter (HI 8424, Hanna Instruments, Portugal) respectively. Nitrate-nitrogen (NO_3-N) and phosphate-phosphorus (PO_4-P) were measured biweekly using an Odyssey DR/2500 spectrophotometer (HACH, USA) following procedure described in the manual. Chlorophyll-*a* and plankton composition were measured biweekly. Chlorophyll-*a* was determined by spectrophotometer after acetone extraction (Greenberg *et al.* 1992). For identification and quantification of plankton, samples were collected by passing a known volume of pond water through 15-μm mesh sized plankton net and the concentrated samples were preserved in 5% buffered formalin. Then quantitative analysis of plankton was done using a Sedgwick-Rafter counting cell (S-R cell, Graticules Ltd.). The plankton on 20 randomly selected fields of the Sedgwick-Rafter counting chamber was counted under a compound microscope. Plankton number (cells/l) was calculated according to Beveridge (1985). Taxonomic identification of phytoplankton was done in the laboratory using the keys described in Edmondson (1959), Prescott (1962) and Bellinger (1992).

The fish growth and feed utilization efficiency of pangasiid catfish was evaluated using specific growth rate (SGR), daily weight gain (DWG), percent weight gain and feed conversion ratio (FCR) indices. At the end of the experiment, the ponds were drained and the fishes were enumerated and measured. A simple economic analysis was done to estimate the economic return in each treatment. The total cost of inputs was calculated and the economic return was determined by the difference between the total return (from the sale of fishes produced) and the total input cost. The cost in taka per unit of yield (CPY) was calculated and was expressed as the cost in Tk/kg of fishes produced.

The data on fish growth, input cost, water quality parameter and economic return were analysed using one-way analysis of variance (ANOVA) to see the differences among the three treatment means. This was followed by least significant difference test (LSD) for paired comparison (Gomez and Gomez 1984). Differences were considered significant at $p<0.05$ confidence level.

Results

Water quality

The ranges and mean values of various physical, chemical and biological water quality parameters in different treatments are presented in Table 1. The surface water temperature in ponds of all treatments ranged from 28.0 °C to 31.8 °C during the study period with no marked variation among the treatments on any sampling day. Water pH ranged from 6.49 to 7.43 and showed a little variation among the ponds of different treatments. Pangasiid catfish monoculture ponds showed significantly lower dissolved oxygen values over polyculture treatments. In general, the dissolved oxygen concentrations showed a decreasing trend with the progress of the culture period in all treatments (Fig. 1). The total alkalinity did not show any definite trend of change during the experimental period. The concentrations of inorganic nitrate-nitrogen and phosphate-phosphorus varied significantly ($p<0.05$) among the treatments. With the progress of the culture period nitrate-nitrogen and phosphate-phosphorus content of ponds' water were found to increase in all treatments, but the rate of increase was higher in T_1 (Fig. 1) than in other treatments.

Table 1. Mean values (± SE, n = 42) and ranges (in parentheses) of water quality parameters observed in ponds of different treatments

Parameters	Treatment 1	Treatment 2	Treatment 3
Temperature	30.38 ± 0.23	30.23 ± 0.10	30.20 ± 0.11
(°C)	(28.20 - 31.50)	(28.00 - 31.83)	(28.20 - 31.33)
Water depth	128.91 ± 3.23	127.69 ± 3.92	129.72 ± 3.85
(cm)	(114.76 -154.43)	(115.42 - 150.98)	(119.33 - 159.88)
Transparency	$18.99^{b} \pm 1.09$	$28.90^{a} \pm 2.28$	$25.44^{a} \pm 2.41$
(cm)	(12.30 - 28.96)	(23.83 - 35.30)	(16.93 - 34.30)
PH	6.85 ± 0.05	7.03 ± 0.05	6.92 ± 0.05
	(6.49 - 7.05)	(6.80 - 7.43)	(6.72 - 7.08)
Dissolved oxygen	$3.71^{b} \pm 0.08$	$4.70^{a} \pm 0.17$	$4.21^{a} \pm 0.09$
(mg/l)	(2.15 - 6.24)	(3.22 - 6.64)	(2.98 - 6.74)
Total alkalinity	99.21 ± 5.98	100.67 ± 4.17	99.54 ± 4.83
(mg/l)	(87.33 - 114.00)	(93.33 - 109.33)	(88.33 - 111.67)
NO_3-N	$2.18^{a} \pm 0.06$	$1.68^{b} \pm 0.06$	$1.94^{a} \pm 0.15$
(mg/l)	(1.10 - 3.07)	(1.20 - 2.10)	(0.90 - 2.50)
PO_4-P	$1.98^{a} \pm 0.07$	$1.37^{b} \pm 0.01$	$1.83^{a} \pm 0.04$
(mg/l)	(0.52 - 3.02)	(0.56 - 1.88)	(0.76 - 2.79)
Chlorophyll-*a*	$549.20^{a} \pm 120.02$	$267.44^{b} \pm 72.62$	$297.25^{b} \pm 66.02$
(μg/l)	(253.64 - 756.97)	(195.66 - 372.35)	(212.73 - 436.60)
Total phytoplankton	$289.06^{a} \pm 64.77$	$141.84^{b} \pm 36.70$	$156.61^{b} \pm 30.14$
(x 10^3cells/l)	(134.15 - 400.53)	(103.52 - 197.01)	(103.24 - 231.01)

*Figures in the same row having the same superscripts are not significantly different ($p>0.05$)

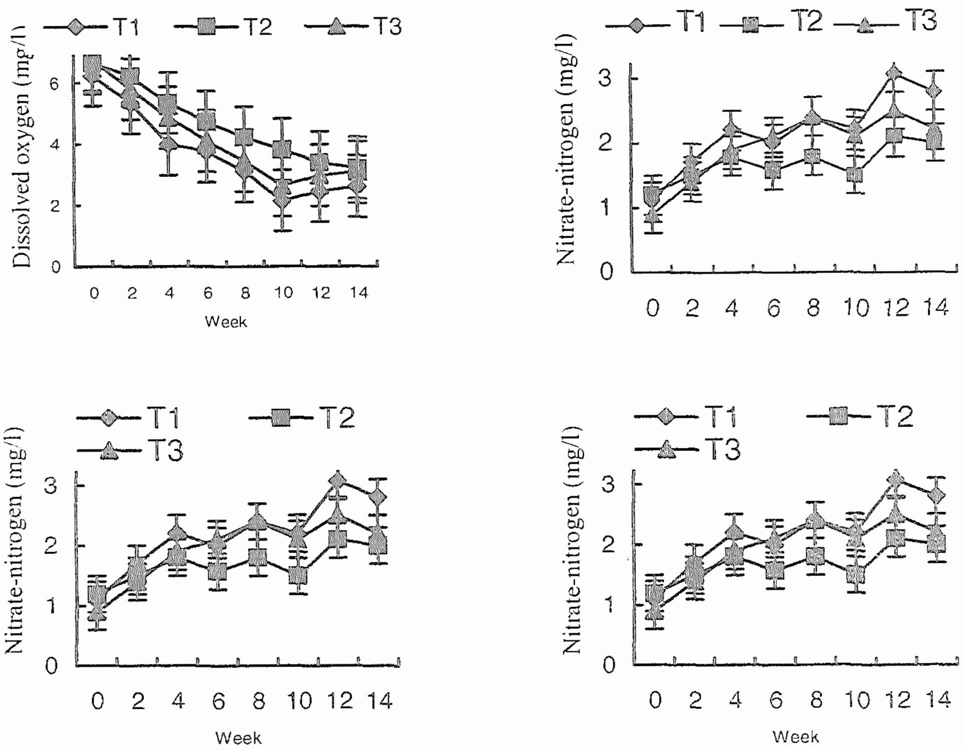

Fig. 1. Changes in dissolved oxygen, nitrate-nitrogen, phosphate-phosphorus and total phytoplankton in ponds of different treatments during the study period.

The growth of phytoplankton was significantly ($p<0.05$) different among the treatments, highest in T_1 and lowest in T_2 (Fig. 1). It was found to increase along with the increase of nitrate-nitrogen and phosphate-phosphorus concentration (Fig. 1). Chlorophyll-*a* content and secchi transparency were found significantly different ($p<0.05$) among the treatments. An inverse relationship was found between chlorophyll-*a* content and secchi transparency. The highest chlorophyll-*a* content and lowest secchi transparency was found in T_1. The phytoplankton population of the experimental ponds comprised of four major groups: Cyanophyceae (9 genera), Chlorophyceae (15 genera), Bacillariophyceae (8 genera) and Euglenophyceae (3 genera).

Growth performance, production and survival of fishes

Growth performance, production and survival of pangasiid catfish and silver carp in different treatments are presented in Table 2. Significantly ($p<0.05$) highest mean final weight and daily weight gain of pangasiid catfish were found in T_2, and in T_3 they were significantly ($p<0.05$) higher than T_1. The SGR and percent weight gain were also significantly ($p<0.05$) highest in T_2, but there was no significant difference between T_3 and T_1. The final weight, DWG, SGR and percent weight gain of silver carp were higher in T_3 than in T_2. Significantly highest ($p<0.05$) production of pangasiid catfish was found in T_1 (12052.7 ± 134.2 kg/ha) and there was no significant difference between T_2 and T_3. The production of silver carp was higher in T_2 than in T_3. The total production of fish was significantly ($p<0.05$) highest in T_1, and there was no significant difference between T_2 and T_3. Survival rate of both pangasiid catfish and silver carp remained high in all treatments ranging from 87 - 93% for pangasiid catfish and 90 - 92% for silver carp with no significant difference among the treatments.

Table 2. Growth performance, production (extrapolated) and survival of pangasiid catfish and silver carp reared for 14 weeks in ponds of three different treatments

Growth indices	Species	Treatment 1	Treatment 2	Treatment 3
Initial length (cm)	Pangasiid catfish	14.41 ± 0.39	13.84 ± 0.12	13.67 ± 0.12
	Silver carp	-	7.63 ± 0.01	7.50 ± 0.02
Final length (cm)	Pangasiid catfish	33.08±0.37	35.39 ± 0.30	33.73±0.21
	Silver carp	-	24.70 ± 0.89	25.87 ± 1.30
Initial weight (g)	Pangasiid catfish	21.01±0.46	21.11 ± 0.42	21.67 ± 0.18
	Silver carp	-	4.90 ± 0.17	4.93 ± 0.09
Final weight (g)	Pangasiid catfish	467.53^c ±6.53	575.60^a ± 2.54	489.43^b ± 3.14
	Silver carp	-	204.97 ± 2.38	249.40 ± 3.70
DWG ($g.day^{-1}$)	Pangasiid catfish	4.56^c ± 0.05	5.91^a ± 0.03	4.77^b ± 0.03
	Silver carp	-	2.04 ± 0.02	2.49 ± 0.04
SGR % ($g.day^{-1}$)	Pangasiid catfish	3.39^b ± 0.09	3.62^a ± 0.14	3.42^b ± 0.13
	Silver carp	-	4.03 ± 0.15	4.28 ± 0.15
Weight gain (%)	Pangasiid catfish	2127.6^b ± 64.8	2629.3^a ± 66.57	2159.24^b ± 4.3
	Silver carp	-	4094.5 ± 167.1	4958.3 ± 111.2
FCR	Pangasiid catfish	1.96^a ± 0.02	1.71^b ± 0.02	1.94^a ± 0.03
PER	Pangasiid catfish	1.82^b ± 0.02	2.09^a ± 0.02	1.85^b ± 0.03
Survival (%)	Pangasiid catfish	87	93	89
	Silver carp	-	90	92
Production (kg./ha)	Pangasiid catfish	12052.7^a ±134.2	7933.15^b ± 98.1	8606.3^b ± 80.0
	Silver carp	-	2734.33 ± 49.13	2266.6 ± 23.2
Total production (kg/ha)	Pangasiid catfish + Silver carp	12052.7^a ±134.2	10667.4^b ± 51.3	10872.9^b ± 87.0

*Figures having the same superscripts in the same row are not significantly different ($p>0.05$)

Significantly ($p<0.05$) low (i.e. good) food conversion ratio (FCR) was found in T_2, and there was no significant difference between T_1 and T_3 (Table 2).

Economic analysis and profitability

The cost of different inputs and economic return from the sale of fishes in different treatments are summarized in Table 3. The cost of inputs and economic return were calculated according to the local price of the inputs used and farm gate price of the fishes produced. The total cost of inputs and economic return per hectare were significantly different ($p<0.05$) among the treatments. The cost of inputs was lowest in T_2 and highest in T_1, and the net economic return was highest in T_2 and lowest in T_1. The cost per unit of yield (25.10-38.12 Tk/kg) was significantly ($p<0.05$) different among the treatments, the lowest was in T_2 (25.10 Tk/kg) and the highest was in T_1 (38.12 Tk/kg).

Price of feed constituted the highest operational cost and showed a positive relationship with the stocking density of pangasiid catfish fingerlings. The required feed cost was highest in pangasiid catfish monoculture treatment and lowest in polyculture of pangasiid catfish with silver carp at the ratio of 1:1. The economic return was not directly related with the total production of fish because of the variations in the cost of inputs in different treatments.

Table 3. Input cost and economic return (extrapolated) in pangasiid catfish monoculture and polyculture with silver carp for 14 weeks in ponds of three different treatments

Component	Treatment 1 (Tk.)	Treatment 2 (Tk.)	Treatment 3 (Tk.)
Cost/ ha			
Pond preparation	1729.00	1729.00	1729.00
Pangasiid catfish fingerling cost @ Tk. 1.75 per fingerling	52500.00	26250.00	35000.00
Silver carp fingerling cost @ Tk. 0.40 per fingerling		6000.00	4000.00
Pelleted feed cost @ Tk. 14.60/kg	373183.30	215145.60	263070.10
Operation cost	32055.92	18684.34	22784.93
Total cost	459468.22^{a}	267808.94^{c}	326584.03^{b}
Retur/ha from sale proceeds			
Pangasiid catfish @ Tk. 45.00/kg	542367.54	356991.57	387291.06
Silver carp @ Tk. 30.00/kg		83836.74	68231.28
Total return	542371.50^{a}	439021.65^{c}	455281.50^{b}
Net return	82903.28^{c}	171212.71^{a}	128691.47^{b}
Cost per unit of yield (Tk/kg)	38.12^{a}	25.10^{c}	30.03^{b}

Operation cost is considered as 7.5% of the total cost (ADCP 1983) 1US\$ = Tk 70.00

Discussion

Water quality

The observed water quality parameters in the farmers' ponds where the study was conducted were within the acceptable range for aquaculture practices and was in conformity with reports explained for farming of different fishes (Hussain 2004, Jena *et al.* 1998). The water temperature ranged from 28.00-31.8 °C and this was due to that the study was conducted in summer months from May to August. The pH was around neutral to slightly alkaline and it was due to local soil condition and natural waters. Moreover, the initial lime treatment during pond preparation possibly helped in maintaining carbon buffer system in the pond water. The slightly lower pH in T_1 and T_3 was perhaps due to acidic reactions during decomposition of unused feed and metabolic wastes as because higher quantity of supplemental feeds were used in those treatments for higher number of stocked pangasiid catfishes than in T_2. The observed decreasing trend in dissolved oxygen content with the progress of the culture period in all treatments was attributed to higher consumption of oxygen in respiration of gradually increased fish biomass (Jena *et al.* 1998) and decomposition of correspondingly increased fish metabolic wastes. The lowest dissolved oxygen in T_1 was perhaps due to highest fish biomass and plankton population. The increasing trend of nitrate-nitrogen and phosphate-phosphorus with the progress of the culture period was obviously due to gradual loading of these nutrients from decomposition of unutilized portion of the gradually increased supplemental feeds and fish metabolic wastes (Jena *et al.* 1998). Both the phytoplankton count and chlorophyll-*a* content were significantly highest in ponds of T_1. Similar phenomena were observed in channel catfish ponds in USA. Boyd (1982) reported that uneaten food supplied more nutrients to algae in channel catfish ponds, because catfish assimilate up to 40% of the nitrogen and 65% of the phosphorus that they consume. Increased inorganic nutrients enhance algal biomass in catfish ponds (Boyd 1985). Silver carps stocked in ponds of other two treatments grazed down the phytoplankton. On the contrary, in T_1, phytoplankton remained unutilized. Moreover, availability of higher amount of nutrients from organic decomposition of unused feed and fish metabolic wastes flourished the phytoplankton growth.

Fish growth and production

Higher growth rates and feed utilization efficiency of pangasiid catfish was found in ponds of T_2 and T_3 where pangasiid catfish and silver carp were cultured together. Similar increment in growth of channel catfish was reported when planktivorous fishes were introduced in catfish ponds (Pretto 1976). In the present study, the higher growth was possibly due to better environmental conditions prevailed in those treatments. The 33 (T_3) - 50% (T_2) pangasiid catfish replaced by surface living silver carp allowed the pangasiid catfish to use the water column more than in monoculture (T_1) ponds. The biological oxygen demand (BOD) and chemical oxygen demand (COD) were expected to be low in T_2 and T_3 because fish and algal biomass as well as unused feed and metabolic wastes were low in those ponds. The silver carps grown in two treatments have not shared pelleted food as it was examined in a parallel on-station experiment (Khan *et al.* unpubl. data) and mainly consumed plankton that helped to get an extra production without feed-cost. Moreover, they helped the environment by grazing down the large-sized colony forming blue-green algae, the cyanophytes, which commonly bloom in pangasiid catfish ponds. The water quality in ponds of all treatments was within acceptable limit and the size and health of the fingerlings at stocking was good that made high survival rate of both pangasiid catfish and silver carp (87-93%) with no significant difference among the treatments. Though the total stocking density of fishes, whether single or multi species, in ponds of the three treatments were the same, the fish biomass production was highest in pangasiid catfish monoculture ponds (T_1) followed by T_3 and T_2 because of the variation in daily weight gain (DWG) between the two fish species, pangasiid catfish and silver carp. Although the daily weight gain of pangasiid catfish in monoculture ponds in T_1 was lowest in comparison to those in T_2 and T_3 but it was much higher than the DWG of silver carp stocked in T_2 and T_3. The higher SGR% and weight gain (%) in case of silver carp than in pangasiid catfish was found due to smaller stocking size in weight of the former species.

Economics and profitability

Along with the increase in production, the purpose of aquaculture practices is to earn a profit. Wyban *et al.* (1988) indicated that stocking density, growth rate, survival rate and market price are the most sensitive factors to increase profit. Improvement of one of these factors sometimes may create undesirable side effects, for example, intensification of culture system, i.e. stocking density requires high food energy expenditure. In our present study the total stocking density of fishes were same in all treatments but the fish species were not same. Pangasiid catfish fingerlings were expensive than the silver carp, and for silver carp no supplemental feed was required, therefore, there was an obvious increase in the feed and fingerling costs with increasing stocking density of pangasiid catfish which resulted in the total production cost higher with higher stocking density of this species. Though the total biomass production and total economic return was significantly highest in pangasiid catfish monoculture ponds (T_1) than in pangasiid catfish and silver carp polyculture (T_2 and T_3), the net economic return was lowest in T_1 because of the required highest input costs specially for supplemental feed and fingerlings as explained above, resulting the highest cost per unit yield (CPY in Tk/kg). Highest cost for supplemental feed required in T_1 was due to highest quantity of feed required for the highest number of pangasiid catfish stocked in that treatment. The findings of the present study suggest that though monoculture of pangasiid catfish give higher fish biomass production but polyculture with silver carp is environmentally good and economically profitable.

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