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# EFFECT OF SPECIES RATIO ON GROWTH AND PRODUCTION OF MAJOR CARP UNDER POLYCULTURE SYSTEM IN *HAOR* REGION

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## Abstract

The study was conducted to assess the effect of species ratio on growth and yield of major carp under polyculture system in perennial ponds for a period of 270 days in *haor* villages of Sunamganj district. The experiment was designated into three treatments ($T_1$, $T_2$ and $T_3$) based on fish species ratio with three replications each. The fingerlings of *Hypophthalmicthys molitrics*, *Gibelion catla*, *Labeo rohita*, *Cirrhinus cirrhosus* and *Cyprinus carpio* were stocked at a ratio of 10, 20, 40, 10, 20; 10, 15, 50, 15, 10, and 20, 10, 30, 20 and 20% in $T_1$, $T_2$ and $T_3$, respectively. Stocked fishes were fed with rice bran and wheat flour at a decreasing rate of 10–5% of body weight twice daily. Significant ($p<0.05$) differences in growth and production among treatments were observed. The highest weight gain of *H. molitrics* (512.89 g), *G. catla* (432.60 g), *L. rohita* (439.99 g), *C. cirrhosus* (346.46 g) and *C. carpio* (379.60 g) observed in $T_2$. Production of *H. molitrics* (802.52–1,477.00 kg ha$^{-1}$), *G. catla* (605.25–1,295.07 kg ha$^{-1}$), *L. rohita* (1,880.01– 3,731.64 kg ha$^{-1}$), *C. cirrhosus* (543.03–951.42 kg ha$^{-1}$) and *C. carpio* (686.66– 1,226.38 kg ha$^{-1}$) varied in different treatments might be due to species ratio. Significantly ($p<0.05$) higher combined production of carp was obtained in $T_2$ (7,444.98 kg ha$^{-1}$) followed by $T_1$ (6,625.27 kg ha$^{-1}$) and $T_3$ (6,007.40 kg ha$^{-1}$). The highest net profit (BDT 213,695.03 ha$^{-1}$) was also obtained in $T_2$ than that of $T_1$ (BDT 172,782.89 ha$^{-1}$) and $T_3$ (BDT 150,440.78 ha$^{-1}$). Result of the study reveals that polyculture of carp like *H. molitrics*, *G. catla*, *L. rohita*, *C. cirrhosus* and *C. carpio* with stocking ratio of 10, 15, 50, 15, 10% in $T_2$ is significantly higher from the viewpoint of growth and production. Therefore, the stocking ratio of 10, 15, 50, 15 and 10% in carp polyculture might be prescribed at farmers' level in order to boost up fish production, uplift the nutritional status as well as accelerate the economic benefit of the farmers.

***Keywords*:** Species ratio, growth, production and perennial ponds.

## Introduction

Bangladesh is one of the world's leading fish producing country with a total production of 41.34 lakh MT, where aquaculture contributed 56.44% (DoF, 2018). In last decade, the average growth potential of this sector is almost 5.43%. Government of Bangladesh is trying to sustain this growth level, which eventually ensures to achieve the probable production target of 45.5 lakh MT by 2020–21 (DoF, 2018). Bangladesh is ranked third and fourth in the world for harvested fish from natural waterbodies and aquaculture production in inland waters, respectively (DoF, 2018). Bangladesh has achieved self-sufficiency in fish production. It is a big achievement for the country. This sector is contributing significantly in food security through providing safe and quality animal protein. Almost 60% animal protein comes from fish. It contributes 3.57% to our national GDP and around one-fourth (25.30%) to the agricultural GDP. Bangladesh earned BDT 4,310.00 crore as foreign currency by exporting 68,935 MT fish and fish products in 2016–17 (DoF, 2018).

Bangladesh is blessed with *haor, baor, beel*, lake, river, estuary, pond and seasonal waterbodies etc. *Haors* are located in the northeast region of Bangladesh, which have a great potential as fisheries resources. Dekar *haor* is one of the most important largest *haor*, which covers about 11,514 ha. It is made up with 36 small, medium and large interconnecting *beels*, canals, rivers and crop lands (Pandit *et al.,* 2015). There is a great importance of this *haor* in fish production, maintaining biodiversity, meeting local and regional demand, and it also serves as the good source of natural fish seed supply to the adjacent waterbodies (Pandit *et al.*, 2015). A total of 51 indigenous and exotic fish species are found in the Dekar *haor* (Suravi *et al.,* 2017).

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Once upon a time people of Bangladesh only depend upon capture fishery but presently people are being practiced with culture fishery utilizing homestead seasonal/perennial ponds, lake and river etc using different culture methods. Among the culture practices mono/polyculture of fish is more common practice in seasonal or perennial ponds. Modern technique of polyculture/mixed culture of fast growing fish has been found as an economically profitable and socially acceptable in perennial/ seasonal waterbodies (Ali *et al*., 2017). Importance of polyculture to accelerate fish production in Bangladesh is well documented (Asadujjaman and Hossain, 2016). The possibilities of increasing fish production through carp polyculture are found the highest compared to other systems (Talukdar *et al.*, 2012). Due to the progress in research and extension activities, aquaculture production in Bangladesh became almost double in last decade and carp alone contributed 45.35% of total fish production in ponds (DoF, 2017).

More fish production in polyculture system results not only through a judicious combination of species, but also depends on stocking ratio, appropriate culture technique including pond preparation, feeding, fertilization and management. For stocking, species selection and ratio are dependent on the nature of soil and primary productivity of pond water, with this the availability of stocking material and consumer's preference are also considered (Milstein *et al*., 2006). Stocking density and species ratio have a direct effect on food supply, space, water quality and water depth. A low stocking density without fish ratio decreases pond yield and increases production cost. Stocking density can be increased with improving culture techniques, careful management and species ratios. In polyculture, different fish species are stocked according to their different feeding habits and relationship between species for higher production and more economic return (Piska, 2005).

People of *haor* villages capture fish from the *haor* in spite of culture. They have no idea about how to maintain species ratio and also stocking density of fish. Their ponds are stocked with randomly selected fish species for polyculture without maintaining species ratio and not considering different water layers of the waterbody. As a result, healthy production of fish is not achieved and they are not financially benefited. Therefore, very little works have been done on species ratio in polyculture system in *haor* areas considering production and income. However, the present study was undertaken to know the effect of species ratio on growth and yield of major carp under polyculture systems in perennial ponds at *haor* villages.

## Materials and Methods

The experiment was conducted in 9 earthen farmers' ponds for a period of 270 days (nine months) from March-November 2017 at *haor* villages (Noagaon and Rabbani Nagor) under Dakhsin Sunamganj *upazila* of Sunamganj district. Average area of each pond was about 0.18 ha. Ponds were completely independent and had no inlet and outlet. Ponds were randomly selected into three treatments having three replicates each.

Before starting the experiment, unwanted fishes were removed from the ponds by repeated netting and using piscicides (phostoxin). Aquatic weeds of the ponds were removed manually and embankments were repaired. Quick lime (CaO) was applied in all ponds at a rate of 250 kg $ha^{-1}$. After one week of liming, the ponds were fertilized with urea and TSP (1:1) at a rate of 50 kg $ha^{-1}$. After 6 days of fertilization, ponds were stocked with fingerlings of *H. molitrics*, *G. catla*, *L. rohita*, *C. cirrhosus* and *C. carpio* at a stocking ratio of 10, 20, 40, 10, 20; 10, 15, 50, 15, 10, and 20, 10, 30, 20 and 20% in $T_1$, $T_2$ and $T_3$, respectively. Stocking density of fingerlings was maintained as 20,000 fish $ha^{-1}$ in all the ponds (Table 1).

**Table 1. Stocking ratio of five carp species in three treatments**

| Fish species | Stocking ratio of fish | | |
|---|---|---|---|
| | $T_1$ (%) | $T_2$ (%) | $T_3$ (%) |
| *Hypophthalmicthys molitrics* | 10 | 10 | 20 |
| *Gibelion catla* | 20 | 15 | 10 |
| *Labeo rohita* | 40 | 50 | 30 |
| *Cirrhinus cirrhosus* | 10 | 15 | 20 |
| *Cyprinus carpio* | 20 | 10 | 20 |
| Total ratio of fish | 100 | 100 | 100 |

Fingerlings of fish were collected from local fish traders of Sylhet. These were transported from hatchery to the experimental site with polythene bags having oxygenation facilities. Then fingerlings were acclimatized with experimental pond water in polythene bags. After that, they were released into the ponds. Before releasing, the weight of 20–25% fingerlings was recorded using weighing balance. The average weight of carp fingerlings was 10.75–12.65 g. After stocking of fish in all ponds, supplementary feed consisting of rice bran and wheat flour/bran (1:1) was applied at a decreasing rate of 10–5% of body weight twice daily. Total daily feed ration was divided into two equal portion and was applied in the morning between 8.00–9.00 am and in the afternoon 3.00–4.00 pm. Feeding was adjusted after fish weighing at every 15 day intervals. Fertilizers (urea and TSP=1:1) were applied at 7–10 day intervals in the ponds to promote plankton growth.

Water quality parameters were recorded at 10 day intervals during 09.00 to 10.00 am. Parameters like temperature, transparency, dissolved oxygen (DO), pH, alkalinity and ammonia-nitrogen were measured. Water temperature was measured *in situ* using a standard centigrade thermometer. Transparency was recorded using Secchi disc. Dissolved oxygen was measured using DO meter (YSI 58 DO meter, Hanna, USA). pH of pond water was recorded using pH meter (Hanna, USA). Total alkalinity was measured by titrimetric method. Ammonia was determined using ammonia test kit (Biosol, A. A. Biotech PVT LTD., Fishtech BD LTD).

Fortnightly sampling of 25–30% fish was done using a small seine net/cast net to calculate fish weight. Growth was measured with digital balance (CAMRY digital electrical balance, EK 3052, Bangladesh) by weight. Behavior of fingerlings was regularly monitored especially after providing feed in the morning and in the afternoon to determine their conditions such as movement, infection and diseases. Sampling was continued until harvesting.

Fish were harvested at the same day after 270 days of culture. Harvesting was done by total draining out of the ponds. After harvesting, all fish of each pond were counted and weighed individually to assess the growth, survival rate and yield performance. Survival rate (%) and production (kg) were calculated following the equation as cited by Pechsiri and Yakupitiyage (2005). The equations are as follows:

Net final weight gain = Mean final weight–mean initial weight

SGR (%/day) = {Ln (final body weight)–Ln (initial body weight) ×100}/Cultured period (days)

Survival rate (%) = (Number of fish harvested ÷ total number of fish stocked) × 100

Production = No. of fish caught × average final weight of fish

Growth, survival rate and production parameters were analyzed using one way analysis of variance (ANOVA) to compare the treatments means. If the main effect was found significant, the ANOVA was followed by Duncan's Multiple Range Test (DMRT). All ANOVA were tested at 5% level of significance using SPSS (Statistical Package for Social Science) version 21.

## Results and Discussion

### Growth and production of fish

After 270 days of culture, fish were harvested from all ponds. Results of different parameters of fish are presented in Table 2. Surface feeder and bottom feeder had different effects on different fish species ratios. *H. molitrics* (512.89±20.25 g) and *G. catla* (432.60±24.58 g) showed significantly ($p<0.05$) higher net weight in $T_2$ followed by $T_1$ (499.53±32.21g and 415.03±24.64 g) and $T_3$ (489.15± 19.84 g and 394.86±21.83 g), respectively. Net weight of *H. molitrics* and *G. catla* obtained in the present study is lower than the findings obtained by Khan *et al.* (2018), who found the net weight of *H. molitrics* and *G. catla* as 841.00±30.11–860.50±21.18 g and 872.75±13.4–1000.05± 6.9 g, respectively in polyculture system with a initial weight of *H. molitrics* and *G. catla* varied from 105.50–107.25 g and 168.25–174.75 g, respectively for six months under Sadar *upazila* of Faridpur district. Farkhanda and Ammara (2017) reported silver carp gained maximum weight of 400.5 g after six month cultured with grass carp and mrigal at a stocking ratio of mrigal, grass carp and silver as 1:3:2, respectively. Mamun and Mahmud (2014) obtained the weight of catla as 347.9 g cultured with rui and mrigal in polyculture systems. The highest net weight of silver carp and catla was 596.85±30.61 and 453.82±23.93 g, respectively recorded by Ahmad *et al.* (2013). The results of the above mentioned researchers support the results of the present study. The weight of *L. rohita* varied between 405.34±34.51–439.99±17.66 g and significantly ($p<0.05$) higher weight was obtained in $T_2$ (439.99±17.66 g) followed by $T_1$ (418.33±38.36 g) and $T_3$ (405.34±34.51 g), which is consistent with the results of Mamun and Mahmud (2014), who found the weight of *L. rohita* as 469.03 g in polyculture systems. Ahmad *et al.* (2013) reported the highest weight of *L. rohita* 354.42±17.52 g, which is lower than the present findings. The finding of the present study is much higher than the findings of Haque *et al*. (1998), who found the net weight of rui as 131.38 g along with initial weight of 2.13 g in mixed culture of catla, common carp and sharpunti for 115 days in a pond of Bangladesh Agricultural University (BAU). Khan *et al*. (2018) found the net weight of *L. rohita* as 444.25±3.64–502.75±8.94 g with initial weight of 74.75–75.75 g, which is higher than the present findings might be due to higher initial weight of fish.

In case of bottom feeder fish (common carp and mrigal), significantly ($p<0.05$) higher net weight was found in $T_2$ (379.60±17.65 and 346.46±38.11 g) than that of $T_1$ (370.13±25.58 and 331.71±36.32 g) and $T_3$ (357.13±22.72 and 308.04±18.89 g), respectively (Table 2). Between bottom feeder, *C. carpio* showed better growth than *C. cirrhosus*. The results of the present study is slightly lower than the findings of Ahmad *et al*. (2013), who reported the net weight of *C. carpio* and *C. cirrhosus* as 466.70±24.165 and 431.58±14.284 g, respectively at a stocking ratio of 1:1.5. The final net weight of *C. mrigala* was 321.67 g in polyculture system recorded by Mamun and Mahmud (2014), which is in agreement with the findings of the present study. The findings of the present study are in similar with the findings of Sinha and Saha (1998), who reported between bottom feeder, *C. carpio* grow better than *C. mrigala* probably due to its superior feed utilizing capability. The present findings coincide with the findings of Milstein *et al.* (2006), who reported farmers prefer to stock *C. carpio* as a bottom feeder instead of *C. mrigala* because *C. carpio* grow faster than *C. mrigala* and the overall production was higher when these species cultured with *L. rohita* and *G. catla* in polyculture ponds.

Survival rate of *H. molitrics, G. catla, L. rohita, C. cirrhosus* and *C. carpio* varied from 73.65–86.95, 74.50–88.23, 75.00–82.50, 72.20–87.3 and 74.00–87.6%, respectively in all treatments during the study period. Comparatively higher survival of all species was found in $T_2$ than the other treatments (Table 2). Survival rate of *L. rohita, C. mrigala* and *G. catla* was 85.42, 81 and 80%, respectively as reported by Mamun and Mahmud (2014). Khan *et al.* (2018) found the survival rate of *H. molitrics, G. catla, L. rohita, C. cirrhosus* and *C. carpio* as 85.75±2.87–87.50±3.86, 91.25±1.25–93.00±1.47, 90.00±2.12–93.50±0.65, 90.00±2.12–91.75±1.31 and 73.00±2.87 –81.25±2.50 %, respectively. Rahman *et al.* (2006) observed the survival rate of *L. rohita* and *C. carpio* as 83.5– 94.5 and 90.7–99.3%, respectively. These findings support the findings of the present study.

Specific growth rate (SGR) of *H. molitrics, G. catla, L. rohita, C. cirrhosus* and *C. carpio* in the present study varied from 1.38–1.40, 1.33–1.38, 1.30–1.33, 1.22–1.25 and 1.26–1.28, respectively. SGR of all fish was higher in $T_2$ except *H. molitrics* (Table 2). Asadujjaman and Hossain (2016) found SGR of *H. molitrics, G. catla, L. rohita, C. mrigala* and *C. carpio* as 1.14±0.31, 1.14±0.32, 0.95±0.26, 1.05±0.25 and 1.09±0.28, respectively in carp polyculture for a period of 6 months. Khan *et al.* (2018) reported the SGR of *H. molitrics, G. catla, L. rohita, C. mrigala,* and *C. carpio* were 1.05±0.01, 1.08±0.02, 1.14±0.01, 1.21±0.04 and 1.18±0.05, respectively in polyculture system for a period of six months. The findings of the above mentioned workers support the findings of the present study.

The production of *H. molitrics* was ranged from 802.52 to 1,477 kg $ha^{-1}$ while the production of *G. catla* varied from 605.25 to 1,295.07 kg $ha^{-1}$. *L. rohita* ranked first in production than other cultured species in all treatments with the highest production (3,731.64 kg $ha^{-1}$) in $T_2$ and the lowest (1,880.01 kg $ha^{-1}$) in $T_3$. The production of bottom feeder *C. cirrhosus* and *C. carpio* ranged from 543.03–951.42 kg $ha^{-1}$ and 686.66–1,226.38 kg $ha^{-1}$. Overall combined production of *H. molitrics, G. catla, L. rohita, C. cirrhosus* and *C. carpio* in $T_1$, $T_2$ and $T_3$, respectively was significantly different from each treatment (Table 2). The highest combined production of all carp was achieved in $T_2$ (7,444.98 kg $ha^{-1}$) followed by $T_1$ (6,625.27 kg $ha^{-1}$) and $T_3$ (6,007.40 kg $ha^{-1}$).

Ali *et al.* (2017) reported the combined production of sarpunti, tilapia and rui ranged from 5,728.67–8,341.41 kg $ha^{-1}$ for 120 days in seasonal ponds of *haor* villages, which is coincided with the findings of the present study. The level of fish production of the present study is higher than the production obtained by Hossain *et al.* (1997), Murty *et al.* (1987) and Wahab *et al.* (1995), who recorded the production of carp species as 3,119–4,067 kg $ha^{-1}year^{-1}$ in traditional polyculture system, 4096 kg $ha^{-1}year^{-1}$ in composite carp species culture with the application of supplementary feed as well as fertilizers and 5,294–5,670 kg $ha^{-1}year^{-1}$ in polyculture of carp with sharpunti, respectively. Islam *et al*. (2016) recorded the production of carp species with tilapia, mola, koi and shing in polyculture systems ranged from 5,187.0–7,904.0 kg $ha^{-1}year^{-1}$, which is almost similar with the present findings. DoF (2018) estimated the fish production in ponds of Bangladesh as 4,765.0 kg $ha^{-1}$. This result is also lower than the results of the present study. The combined production of this study is comparatively much lower than the combined production demonstrated by Kohinoor *et al.* (2016), who recorded the production of koi, shing and tilapia as 23,094.25 kg $ha^{-1}$ in polyculture system at on station ponds for 120 days.

**Table 2. Growth, survival, production and net profit (mean±SD) of carp species in polyculture system during the study period**

| Variables | Treatments | | |
|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ |
| *Hypophthalmicthys molitrics* | | | |
| Stocking density $ha^{-1}$ | 2,000 | 2,000 | 4,000 |
| Average initial weight (g) | 11.63±0.47 | 12.51±0.53 | 12.21±0.48 |
| Average final weight (g) | 511.16±32.68 | 525.40±20.78 | 501.36±20.32 |
| Net final weight gain (g) | 499.53±32.21$^{b}$ | 512.89±20.25$^{a}$ | 489.15± 19.84$^{c}$ |
| Survival rate (%) | 78.50$^{b}$ | 86.95$^{a}$ | 73.65$^{c}$ |
| Specific growth rate (% $day^{-1}$) | 1.40 | 1.38 | 1.38 |
| Production (kg $ha^{-1}$) | 802.52 | 913.67 | 1,477.00 |
| *Gibelion catla* | | | |
| Stocking density $ha^{-1}$ | 4,000 | 3,000 | 2,000 |
| Average initial weight (g) | 10.98±0.58 | 10.75±0.50 | 11.35±0.63 |
| Average final weight (g) | 426.01±25.24 | 443.35±25.08 | 406.21±22.45 |
| Net final weight gain (g) | 415.03±24.64$^{b}$ | 432.60±24.58$^{a}$ | 394.86±21.83$^{c}$ |
| Survival rate (%) | 76.00$^{b}$ | 88.23$^{a}$ | 74.50$^{b}$ |
| Specific growth rate (% $day^{-1}$) | 1.35 | 1.38 | 1.33 |
| Production (kg $ha^{-1}$) | 1,295.07 | 1,173.55 | 605.25 |
| *Labeo rohita* | | | |
| Stocking density $ha^{-1}$ | 8,000 | 10,000 | 6,000 |
| Average initial weight (g) | 12.65±0.66 | 12.33±0.89 | 12.44±0.68 |
| Average final weight (g) | 430.98±39.02 | 452.32±18.52 | 417.78±35.19 |
| Net final weight gain (g) | 418.33±38.36$^{b}$ | 439.99±17.66$^{a}$ | 405.34±34.51$^{c}$ |
| Survival rate (%) | 80.00$^{a}$ | 82.50$^{a}$ | 75.00$^{b}$ |
| Specific growth rate (% $day^{-1}$) | 1.31 | 1.33 | 1.30 |
| Production (kg $ha^{-1}$) | 2,758.27 | 3,731.64 | 1,880.01 |
| *Cirrhinus cirrhosus* | | | |
| Stocking density $ha^{-1}$ | 2,000 | 3,000 | 4,000 |
| Average initial weight (g) | 11.98±0.93 | 12.25±1.12 | 11.96±0.90 |
| Average final weight (g) | 343.69±35.89 | 358.71±39.23 | 320.56±19.79 |
| Net final weight gain (g) | 331.71±36.32$^{b}$ | 346.46±38.11$^{a}$ | 308.04±18.89$^{c}$ |
| Survival rate (%) | 79.00$^{b}$ | 87.30$^{a}$ | 72.20$^{c}$ |
| Specific growth rate (% $day^{-1}$) | 1.24 | 1.25 | 1.22 |
| Production (kg $ha^{-1}$) | 543.03 | 939.46 | 951.42 |
| *Cyprinus carpio* | | | |
| Stocking density $ha^{-1}$ | 4,000 | 2,000 | 4,000 |
| Average initial weight (g) | 12.04±1.38 | 12.33±0.92 | 12.37±0.95 |
| Average final weight (g) | 382.17±26.97 | 391.93±18.57 | 369.50±23.68 |
| Net final weight gain (g) | 370.13±25.58$^{b}$ | 379.60±17.65$^{a}$ | 357.13±22.72$^{c}$ |
| Survival rate (%) | 80.23$^{b}$ | 87.60$^{a}$ | 74.00$^{c}$ |
| Specific growth rate (% $day^{-1}$) | 1.28 | 1.28 | 1.26 |
| Production (kg $ha^{-1}$) | 1,226.38 | 686.66 | 1,093.72 |
| Combined production (kg $ha^{-1}$) | 6,625.27±46.20$^{b}$ | 7,444.98±40.39$^{a}$ | 6,007.40±37.14$^{c}$ |
| Net profit (BDT $ha^{-1}$) | 172,782.89±1432.10 | 213,695.03±2159.31 | 150,440.78±973.62 |
| Benefit cost ratio (BCR) | 1:1.49 | 1:1.56 | 1:1.43 |

Mean values in the same row with same superscript letters are not significantly different (p>0.05).

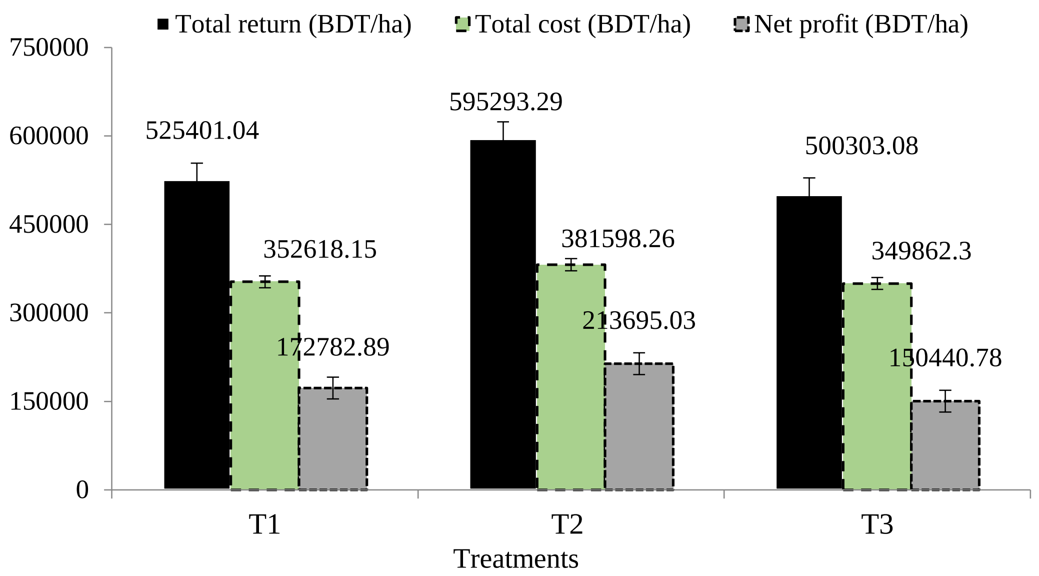


**Fig. 1. Economic analysis of carp polyculture in three different treatments**

The net profit obtained in $T_1$, $T_2$ and $T_3$ was BDT 172782.89, 213695.03 and 150440.78, respectively. The highest net profit (BDT 213695.03) and cost benefit ratio (1:1.56) were found in $T_2$ where the ponds were stocked with carp species at a ratio of 10, 15, 50, 15 and 10%. The lowest profit (BDT 150440.78) and BCR (1:1.43) of this study were recorded in $T_3$ (Table 2 and Fig. 1). This finding is slightly higher than the findings obtained by Asadujjaman and Hossain (2016), who recorded the net benefit and BCR as BDT 1, 11, 639.90–2,06,744.85 and 0.77–1.67, respectively in carp polyculture for 6 months at a stocking density of 11,115 fish ha$^{-1}$. Islam *et al.* (2016) demonstrated the net income ranged from BDT 1, 66, 478.00–2, 42, 060.00 in polyculture system with mola and tilapia at a stocking density of 18,750–46,250 fish ha$^{-1}$ for 5 months, which is in agreement with the findings of the present study. Khan *et al.* (2018) found the BCR in carp polyculture ranged from 1.24–1.42 at a stocking density of 6916 fish ha$^{-1}$ for 6 months in Faridpur district, which is also lower than the findings of the present study.

**Water quality parameters**

The results of water quality parameters like temperature, transparency, DO, pH, alkalinity and ammonia are presented in Table 3. All parameters of water of the ponds were found within the acceptable ranges for fish culture. In the present study, water temperature was between 27±1.9–30.5±1.8ºC during culture period. Das *et al.* (2018) found water temperature varied from 28.7 to 29.1.0ºC at Dekar *haor* and Begum *et al.* (2017) found 28.7ºC in ponds of SAU Campus. These findings support the present findings. On the other hand, the present result is higher than the findings of Ali *et al.* (2017), who recorded temperature ranged from 22.9 to 23.5ºC in polyculture of sarpunti, tilapia and rui at same density in seasonal ponds at *haor* villages for 120 days. This might be due to the variation of stocking time and duration of culture period.

**Table 3. Water quality parameters (mean±SD) recorded from ponds under three treatments during the study period**

| Parameters | Treatments | | |
|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ |
| Temperature ($^{o}$C) | 27±1.8 | 27.2±1.9 | 30.5±1.8 |
| Transparency (cm) | 26.4±1.48 | 29.5±1.25 | 28.9±1.48 |
| DO (mg l$^{-1}$) | 4.9±0.44 | 4.5±0.39 | 5.1±0.79 |
| pH | 6.7 (7.0–7.3) | 6.9 (7.0–7.6) | 7.0 (7.0–7.7) |
| Total alkalinity (mg l$^{-1}$) | 122.10±2.62 | 125.11±2.70 | 128.10±2.62 |
| $NH_3$-N (mg l$^{-1}$) | 0.01±0.002 | 0.01±0.001 | 0.03±0.001 |

Water transparency varied from 26.4±1.48–29.5±1.25 cm, which supports the findings of Ali *et al.* (2017), who recorded mean transparency ranged from 23.8–24.5 cm. Begum *et al.* (2017) and Das *et al.* (2018) reported water transparency between 34.35±1.52–36.33±1.48 cm and 33.34–36.24 cm in a cage culture system at a pond of SAU and Dekar *haor*, respectively, which are higher than the present findings. Boyd (1982) stated that suitable transparency range for fish culture is within 15–40 cm.

Dissolved oxygen (DO) concentration obtained 4.5 to 5.1 mg $l^{-1}$, which is supported by the findings of Ali *et al*. (2017) and Das *et al.* (2018), who recorded DO ranged from 4.9–5.25 mg $l^{-1}$ and 6.11–6.88 mg $l^{-1}$, respectively in season ponds and in cage culture at Dekar *haor*. pH was observed 6.3 to 7.2, which is supported by Ali *et al.* (2017) who reported pH values 6.9–7.3 in seasonal ponds and Das *et al.* (2018) recorded the value of pH between 6.5 to 7.02 in the Dekar *haor*. Swingle (1969) stated that the optimum range of pH should be maintained from 6.5 to 9.0 for maximum growth and production of fish. These findings coincide with the findings of the present study. Fortnightly values of alkalinity was 122.10 to 128.10 mg $l^{-1}$ in present study, which is in agreement with the findings obtained by Ali *et al.* (2017) and Das *et al*. (2018), who recorded 125.11±2.7–132.20±2.6 mg $l^{-1}$ and 118.10 –127.20 mg $l^{-1}$ total alkalinity in seasonal ponds and in *haor*. Concentrations of ammonia-nitrogen varied from 0.01 ±0.002–0.03± 0.001 mg $l^{-1}$. Begum *et al.* (2017) and Das (2018) recorded 0.010 to 0.013 mg $l^{-1}$ and 0.01–0.07 mg $l^{-1}$ ammonia concentration, respectively in SAU pond and in cage culture in *haor*, which are consistent with the present findings.

Bangladesh has a large number of perennial ponds, which are scattered in different parts of the country. Total area of these ponds is about 3, 84,700 ha (DoF, 2018). This vast area is not properly used for fish culture. Most of the farmers' culture different fish species in their ponds without considering stocking ratio and stocking density. As a result, they are not getting better production and lucrative income. But there is a great scope to increase fish production and profit of the fish farmers to bring these waterbodies under modern fish culture practices. Stocking ratio of carp species based on food and feeding habit of fish, and water layer in polyculture system is very much important factor, which directly enhances fish production as well as net return. Results of the present study are clearly indicated that among three treatments better yield and high net profit were found in $T_2$ where ponds were stocked with Indian and Chinese major carp at a ratio of 10, 15, 50, 15 and 10 %. Therefore, it may be concluded that in carp polyculture stocking ratio should be maintained very efficiently because stocking ratio increases fish production and economic return very significantly.

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