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ORIGINAL RESEARCH ARTICLE



## Determination of suitable species combination for good aquaculture practice based carp fattening in ponds under drought prone *barind* area of Bangladesh

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### ABSTRACT

Increased temperature, decreased water level and reduced culture period of the ponds with lack of guidelines in selecting appropriate stocking size, density and combination of species are major constraints for safe production of fattening based carps in drought prone *barind* area of Bangladesh. In order to address these problems, an experiment was conducted during July-December, 2018 to determine the suitable species combination for fattening ponds of overwintered carps in Tanore upazila (sub district) of Rajshahi district, Bangladesh. Three different combinations of surface (*G. catla* and *H. molitrix*), column (*L. rohita*) and bottom (*C. cirrhosus* and *C. carpio* var. *specularis*) feeding carp species were tested under 3 treatments (T<sub>1</sub>, T<sub>2</sub> and T<sub>3</sub>), each with 3 replications: T<sub>1</sub> (Surface-30%, column-40%, and bottom-30%), T<sub>2</sub> (Surface-40%, column-30%, and bottom-30%) and T<sub>3</sub> (Surface-35%, column-35%, and bottom-30%). Application of good aquaculture practices in the studied ponds was found to improve the environmental conditions of pond. Significantly ( $P < 0.05$ ) highest fish yield was obtained from treatment T<sub>2</sub> which was 21.47% and 11.89% higher than T<sub>1</sub> and T<sub>3</sub>, respectively. Significantly ( $P < 0.05$ ) highest cost benefit ratio was recorded with treatment T<sub>2</sub> ( $0.42 \pm 0.02$ ) followed by T<sub>3</sub> ( $0.31 \pm 0.01$ ) and T<sub>1</sub> ( $0.21 \pm 0.01$ ), respectively. Inclusion of appropriate number of fishes at different water layers of pond favoured the yield and economics of carp fattening. The study also suggests focusing on optimal stocking density together with the formulation of low cost feed for carp fattening in ponds under *barind* area of Bangladesh.

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### INTRODUCTION

Bangladesh is now the fifth biggest fish producer in the world after China, India, Vietnam and Indonesia (FAO, 2018). Approximately 60 percent of animal protein comes from fish, and the fisheries sector contributes 3.57 percent to the country's GDP. This is possible due to the rapid aquaculture growth in Bangladesh. Although the country has gained self-sufficiency in terms of agricultural production, productivity needs to be increased to meet the needs of the growing population. In that case, pond culture represents huge potentiality accounting for 44.43% of the total recorded production and 57.70% of the area under

culture and it has the potentiality to increase further (DoF, 2019). Dominating species for pond aquaculture are Indian major carps and exotic carps (Hasan and Ahmed, 2002). However, potentiality of carp polyculture is beyond to the reach to be sustainable due to climate change which makes the fisheries sector of Bangladesh vulnerable to environmental degradation in various magnitudes; such as ground water sinking and contamination through pollutants (DoF, 2017). This phenomenon is mostly true for the northwest part of Bangladesh which is a typical *barind* tract region characterized by red or yellow clay soil, limited rainfall and lack of water sources in the dry season. In these consequences, poor survival and reduced growth of

cultured fish species are evident frequently in *barind* area (Hossain, 2011). Appropriate technique is thus felt necessary to increase fish production in vulnerable *barind* area due to climate change. Fattening is a popular technique to increase biomass in animal rearing and this practice is often followed for the production of beef cattle (Sarma *et al.*, 2014) and crab (Ferdoushi, 2013) in Bangladesh. Stocking of over wintered and larger size fish species in carp fattening is considered beneficial to mitigate the fish culture problem of lower water column under drought prone *barind* area because overwintering is a proven technique to obtain the fast growth of fish (Alam *et al.*, 2002; Jobling, 2010) and larger stocking size under lower density can help to obtain maximum fish biomass within shorter period of time (Grover *et al.*, 2000). However, appropriate selection of species combination; judicious utilization of inputs like feed and fertilizers; and proper application of good aquaculture practices (GAP) should also be considered important for sustainability of carp fattening technique. Selection of suitable species combination in polyculture system is important to obtain maximum fish production through the total utilization of different trophic and spatial niches of a pond. Species combination should include species with diversified feeding habit that should include surface, column and bottom feeder fish species (Bhanu *et al.*, 2018; Azad *et al.*, 2004). Appropriate species combination can also improve pond environment. Surface feeder silver carp can control unwanted algal bloom and the bottom feeder mrigal, common or mirror carp can help in the re-suspension of bottom nutrients to water while stirring the bottom mud in search of food (Talukder *et al.*, 2018). On the other hand, where there is effort for aquaculture intensification, there is a chance of environmental degradation and disease occurrence especially in feed and fertilizer based system. Public health is therefore being of prime concern. It is suspected that the organic wastes improve the nutrients levels in the ponds, a situation that will increase the plankton productivity and it is ideal for fish growth, but enhances the conditions where pathogenic bacteria can introduce into

the ponds and increase the risk of transfer of some zoonotic disease from the fish to the human (Herbst *et al.*, 2008). Good aquaculture practice (GAP) is a series of activities from pond preparation to harvesting necessary to maintain the proper hygienic condition of the culture ponds (Schwarz *et al.*, 2010). Poor construction and maintenance of the ponds results in unfavourable physico-chemical condition of the pond water that interferes with the productivity of fish in pond (Mondal *et al.*, 2016). There are some research efforts to mitigate the low alkalinity and high turbidity problems and to use the larger stocking size of fish than traditional practice (Talukder *et al.*, 2018) towards increase in fish production in carp polyculture ponds under *barind* area. Unfortunately no comprehensive effort is taken for safe fish production through carp fattening in ponds under *barind* area of Bangladesh. However, based on the climate change effects on fish production, this study for the first time applied GAP aspects and fattening technique together with the motto to find out suitable carp species combination in ponds under drought prone *barind* area. The specific objectives of this study were to monitor the environmental parameters; to evaluate fish growth, yield and economics of carp fattening; and to recommend suitable carp species combination for fattening ponds under *barind* area of Bangladesh.

## MATERIALS AND METHODS

### Location and duration of study

The present experiment was conducted for a period of 6 months from July to December, 2018 in ponds (Mean area, depth and age of  $0.64 \pm 0.07$  ha,  $1.99 \pm 0.05$  m and  $10.56 \pm 1.29$  years, respectively) of Tanore upazila under Rajshahi district, Bangladesh (Figure 1). Experimental ponds were well exposed to sunlight and facilitated through inlets and outlets for water drainage. Embankments of the ponds were high enough to protect the run off.



Figure 1. Location of study area indicated with red circle at Tanore upazila of Rajshahi district, Bangladesh.

**Table 1.** Layout of experimental design.

Parameters	Treatments								
	T <sub>1</sub> (Surface-30%, column-40%, and bottom-30%)			T <sub>2</sub> (Surface-40%, column-30%, and bottom-30%)			T <sub>3</sub> (Surface-35%, column-35%, and bottom-30%)		
	T <sub>1</sub> R <sub>1</sub>	T <sub>1</sub> R <sub>2</sub>	T <sub>1</sub> R <sub>3</sub>	T <sub>2</sub> R <sub>1</sub>	T <sub>2</sub> R <sub>2</sub>	T <sub>2</sub> R <sub>3</sub>	T <sub>3</sub> R <sub>1</sub>	T <sub>3</sub> R <sub>2</sub>	T <sub>3</sub> R <sub>3</sub>
Pond area (ha)	0.27	0.80	0.53	0.80	0.53	0.53	0.67	0.53	0.33
Pond depth (m)	1.64	1.68	1.66	1.69	1.71	1.67	1.65	1.68	1.68
Stocked carps (nos/pond)	667	1976	1309	1976	1309	1309	1655	1309	815

### Experimental design

A randomized completely block design (RCBD) was followed for carrying out the present experiment with three different treatments of carp species combinations like T<sub>1</sub>: surface feeder-30%, column feeder-40%, and bottom feeder-30%; T<sub>2</sub>: surface feeder-40%, column feeder-30% and bottom feeder-30%; and T<sub>3</sub>: surface feeder-35%, column feeder-35% and bottom feeder-30%. Each treatment had three replications. Two surface feeders namely catla, *Gibelion catla* and silver carp, *Hypophthalmichthys molitrix*; one column feeder namely rohu, *Labeo rohita*; and two bottom feeders namely mrigal, *Cirrhinus cirrhosus* and carpio *Cyprinus carpio var. specularis* were used in the present experiment (Table 1). Stocking densities of the carps (2470 fishes/ha) were same for all the treatments. Stocking size of the fishes were 413.11±1.39, 410.56±1.84, 406.00±5.20, 340.55±4.02 and 248.78±1.35 g for *G. catla*, *H. molitrix*, *L. rohita*, *C. cirrhosus* and *C. carpio var. specularis*, respectively.

### Pond management

Experimental ponds were subjected to removal of aquatic weeds manually. Predatory and unwanted fishes were removed through repeated netting. Ground water was used for all the ponds to maintain the water depth of around 2.0 m throughout the culture period. Both wild (Indian major carps) and hatchery (exotic carps) seeds reared through overwintering were used for stocking into the ponds under different treatments. Considering the soil and water quality of *barind* area of Bangladesh, low alkalinity and high turbidity mitigation strategy for the ponds was followed through lime treatment (Basal dose 750 kg/ha and periodic dose 60 kg/ha/fortnight) after Hossain (2011). Guideline for GAP aspects was followed after DoF (2012) and no organic manure was used except limited use of inorganic fertilizers (urea @ 120 kg/ha/month and triple super phosphate, TSP @ 635 kg/ha/month) to enhance the natural feed and regular use of supplementary feed to increase the fish growth. Fishes were fed with commercial feed (25% protein content) twice daily at average 5% of body weight 6% for 4 months and 3% for rest of the study period.

### Monitoring of environmental parameters

Water quality parameters of the experimental ponds were monitored between 09:00 am and 10:00 am in each month. Water temperature was recorded with the help of a Celsius thermometer at 20-30 cm below the water surface. Water transparency (cm) was measured by a Secchi disk. Alkalinity (mg/l) and ammonia-nitrogen (mg/l) were determined by the

help of a HACH kit (FF2, USA). Dissolved oxygen (mg/l), pH and total dissolved solids (TDS) were determined by a Multimeter (HQ 40 D, HACH, USA). Plankton was identified using the key after Ward and Whipple (1959), Prescott (1962) and Bellinger (1992) and their concentration in water was determined by the help of a microscope after Stirling (1985). For heavy metal analysis, water samples from all studied ponds were collected at a depth of about 0.3 m below water surface into 500 ml plastic bottles. Prior to sampling, the bottles were cleaned with 10% nitric acid and rinsed with distilled water. The bottles were rinsed three times with the pond water at the time of sampling. Immediately after sample collection, 2 ml nitric acid was added to the water samples to reduce adsorption of metals onto the walls of the plastic bottles. Sample bottles were then labeled to indicate date of sampling and the sampling pond. Samples were transported in an ice-box to the laboratory and stored at 4 °C awaiting analysis. Samples were digested through concentrated HNO<sub>3</sub> and hydrogen peroxide acid (5 ml) and the determination of cadmium (Cd) and lead (Pb) concentrations were carried out by the use of Flame Atomic Absorption Spectrometer (Shimadzu, AA-6800) in central lab of University of Rajshahi, Rajshahi. For the bacteriological analysis, 500 ml of water samples were sampled from each studied ponds. The sample was labeled and stored in the dark to prevent the entry of light and photolysis. The sample was delivered to the laboratory of Department of Fisheries, University of Rajshahi, Bangladesh as quickly as possible i.e. the time gap between sampling and analysis was maintained below 3 h. In the laboratory, total heterotrophic bacterial (THB) count was done in plate count agar and *Pseudomonas* and *Aeromonas* in GSP Agar (*Pseudomonas Aeromonas* Selective Agar Base), *Salmonella* and *Shigella* in SS Agar plate (Hi Media). Two steps were followed to analyze *Escherichia coli* in pond water samples. Firstly, total and fecal coliform were detected in MacConkey Agar plate and secondly, the colony of bacterial cells appeared as green metallic sheen in MacConkey Agar plate were tested for *E. coli* after the confirmation with biochemical test (iMVIC test). Colony counts were made from plates with a digital colony counter and expressed as colony forming units (cfu/ml) of the sample.

### Fish growth monitoring

Fortnightly sampling of fishes were done to monitor growth performance and adjustment of the feeding ration. In each sampling date, 10% of the stocked fishes of each species were caught from each pond with the help of a seine net for the study

of growth performances of fishes. The examined fishes were then immediately released into the ponds without any harm. Growth, survival and production performances of fishes were analyzed after Brett and Groves (1979) as follows:

Initial weight (g) = Weight of fish at stock

Final weight (g) = Weight of fish at harvest

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

$$\text{Specific Growth Rate SGR (\%, bw/d)} = \frac{L_n \text{ final weight} - L_n \text{ initial weight}}{\text{Culture period}} \times 100$$

$$\text{Survival rate (\%)} = \frac{\text{No. of fish harvested}}{\text{No. of fish stocked}} \times 100$$

Fish yield (kg/ha) = Fish biomass at harvest - Fish biomass at stock

### Economic analysis

Cost-benefit analysis of different treatments was calculated on the basis of the cost of lime, ash, fertilizer, fish seed and labor used; and the income from the sale of fishes. The prices are expressed in Bangladesh currency (BDT; 80 BDT = 1 USD).

The following simple equation was used according to Asaduzzaman et al. (2010) to find out net return:  $R = I - (FC + VC + li)$  Where, R = net return, I = income from fish sale, FC = fixed/common costs, VC = variable costs and li = interest on inputs

The benefit-cost ratio was determined as:

Cost-benefit ratio (CBR) = Net benefit/Total input cost

### Statistical analysis

Environmental parameters; fish growth and yield; and economics of carp fattening under different treatments were analyzed by one-way analysis of variance (ANOVA). When a mean effect was significant, the ANOVA was followed by Duncan New Multiple Range Test (Duncan, 1995) at 5% level of significance (Gomez and Gomez, 1984). The percentages and ratio data were analyzed using arcsine transformed data. All analyses were performed using SPSS (Statistical Package for Social Science) version 20.0 (IBM Corporation, Armonk, NY, USA).

## RESULTS AND DISCUSSION

### Environmental parameters

Variations in the mean values of environmental parameters are shown in Table 2. During the study period, no significant ( $P < 0.05$ ) effect of different combination of fish species was observed on temperature, DO, pH and alkalinity of the pond water and all the parameters were within the suitable limit for carp polyculture (Bhatnagar and Devi, 2013; Saloom and Duncan, 2005; Boyd, 1998). However, treatments having 30% and 40% of surface feeder fishes showed a significant variation ( $P < 0.05$ ) in transparency and  $\text{NH}_3\text{-N}$  concentration of water. Transparency was

higher at Treatment  $T_1$  and  $\text{NH}_3\text{-N}$  at  $T_2$ . These features could be explained by the amount of fecal materials disposed by surface feeder fishes (*H. molitrix* and *G. catla*). The quantity and quality of fecal materials produced is species, feed and system dependent (Verdegem, 2013). Herbivorous (*H. molitrix* and *G. catla*) and omnivorous (*L. rohita*) are capable of utilizing higher carbohydrate and lower dietary protein from supplementary feed (Raj et al., 2008), therefore, produces larger amount of ammonia in water and a concurrent increase of plankton density which reduces the water transparency. Thus, higher percentage of surface feeding herbivorous at Treatment  $T_2$  in the present study might be responsible for significantly lower transparency, higher  $\text{NH}_3\text{-N}$  and higher plankton cell density. However, the water quality parameters recorded during the study period were more or less similar to the findings of Talukder et al. (2017 and 2018) and Hossain (2011), who also conducted their research on barind area of Bangladesh. During the study period, concentrations of heavy metals (Cd and Pb) were not varied significantly ( $P > 0.05$ ) among the treatments and the values obtained at different treatment were below the permissible level according to WHO (1993). The only sources of these two metals in water are anthropogenic activities such as disposal of raw sewage, application of pesticides and inorganic fertilizers as well as industrial waste materials (Sultana et al., 2017; Aladesanmi et al., 2014; Haiyan and Stuanes, 2003). During the study period, possible contaminant of the experimental ponds was eliminated through the proper implementation of good aquaculture practice (GAP). However, the lower concentration of Cd and Pb detected during the study period might be come from supplementary feed as Kundu et al. (2017) had previously reported that raw materials used for commercial feed sometimes tends to be contaminated with heavy metals. Execution of GAP also had profound effect on bacterial cell density in the experimental ponds. As the bacterial count in the pond ecosystem is linked to the management aspects of pond, the range of total heterotrophic bacterial count ( $2.86 \pm 0.09$  at  $T_2$  to  $3.21 \pm 0.27$  at  $T_1$ ) was much lower compared to the findings of Ampofo and Clerk (2010), Jha et al. (2008) and Banu et al. (2001). However, different combination of fish species did not show any significant effect on the total cell density of THB among the treatments. Moreover, the appearance of both indigenous (*Pseudomonas* and *Aeromonas*) and non-indigenous (*Salmonella*, *Shigella* and *Escherichia coli*) pathogenic bacteria were absent in all the treatments. Previous studies have shown that different kinds of livestock manure and human fecal materials are the main source of pathogenic bacteria in fish culture pond (Joseph et al., 2017; Yagoub, 2009; Musaiger and Souza, 2008; Abdelhamid et al., 2006; Apha, 2005; Chao et al., 2003). Therefore, in the present study, GAP aspects taken during pond preparation such as proper construction of pond dike, liming, fertilization and supplementation of only commercial fish feed become proved beneficial to get rid of the pathogenic bacteria from pond water. However, there was no noticeable effect of environmental parameters were observed on productivity of fish species during the study period.

**Table 2.** Environmental parameters under different treatments of carp fattening in ponds.

Environmental parameters	Treatments			F-value	P-value
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>		
Temperature (°C)	26.55±0.03 <sup>a</sup>	26.35±0.09.26 <sup>a</sup>	26.20±0.17 <sup>a</sup>	0.910	0.450
DO (mg/l)	5.59±0.04 <sup>a</sup>	6.06±0.06 <sup>a</sup>	5.88±0.06 <sup>a</sup>	26.370	0.325
pH	7.04±0.02 <sup>a</sup>	7.15±0.03 <sup>a</sup>	7.04±0.01 <sup>a</sup>	2.400	0.170
Alkalinity (mg/l)	134.72±1.11 <sup>a</sup>	137.77±2.64 <sup>a</sup>	133.33±1.27 <sup>a</sup>	1.570	0.280
Transparency (cm)	23.16±0.42 <sup>a</sup>	19.72±0.20 <sup>c</sup>	21.22±0.20 <sup>b</sup>	34.681	0.000
NH <sub>3</sub> -N (mg/l)	0.02±0.00 <sup>b</sup>	0.04±0.00 <sup>a</sup>	0.02±0.00 <sup>b</sup>	21.502	0.000
Cadmium (mg/l)	0.010±0.001 <sup>a</sup>	0.009±0.002 <sup>a</sup>	0.007±0.001 <sup>a</sup>	36.563	0.636
Lead (mg/l)	0.003±0.001 <sup>a</sup>	0.002±0.001 <sup>a</sup>	0.003±0.002 <sup>a</sup>	46.891	0.765
Plankton(×10 <sup>4</sup> cells/l)	7.06±0.76 <sup>b</sup>	19.04±1.98 <sup>a</sup>	16.85±1.08 <sup>a</sup>	22.272	0.000
THB (×10 <sup>4</sup> cfu/ml)	3.21±0.27 <sup>a</sup>	2.86±0.09 <sup>a</sup>	3.18±0.05 <sup>a</sup>	122.213	0.654
<i>Pseudomonas</i> (cfu/ml)	0.00	0.00	0.00	-	-
<i>Aeromonas</i> (cfu/ml)	0.00	0.00	0.00	-	-
<i>Salmonella</i> (cfu/ml)	0.00	0.00	0.00	-	-
<i>Shigella</i> (cfu/ml)	0.00	0.00	0.00	-	-
<i>Escherichia coli</i> (cfu/ml)	0.00	0.00	0.00	-	-

Figures bearing common letter(s) in a row as superscript do not differ significantly (P>0.05). BDL = Below detection limit.

**Table 3.** Fish yield (kg/ha/6 months) under different treatments of carp fattening in ponds.

Species	Treatments			F-value	P-value
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>		
<i>G. catla</i>	1014.82±8.62 <sup>c</sup>	1378.09±17.87 <sup>b</sup>	1189.78±24.52 <sup>a</sup>	99.561	0.000
<i>H. molitrix</i>	692.99±15.88 <sup>c</sup>	897.59±10.64 <sup>b</sup>	821.25±7.85 <sup>a</sup>	75.102	0.000
<i>L. rohita</i>	885.71±20.68 <sup>b</sup>	1006.54±35.306 <sup>a</sup>	869.24±4.09 <sup>b</sup>	9.971	0.012
<i>C. mrigala</i>	565.03±8.63 <sup>a</sup>	590.38±46.898 <sup>a</sup>	555.35±10.03 <sup>a</sup>	5.910	0.238
<i>C. carpio var. specularis</i>	292.95±11.49 <sup>a</sup>	319.94±5.56 <sup>a</sup>	311.36±8.87 <sup>a</sup>	6.960	0.327
All species	3451.50±32.62 <sup>c</sup>	4192.54±79.37 <sup>a</sup>	3746.98±33.91 <sup>b</sup>	67.413	0.000

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

**Table 4.** Economics of carp fattening (ha/6 months) under different treatments.

Items	Treatments			F value	P value
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>		
Variable cost (BDT/ha)					
Seed	130336.15±387.88 <sup>a</sup>	128177.36±74.29 <sup>b</sup>	128035.99±421.54 <sup>b</sup>	11.712	0.000
Feed	484766.66±2304.29 <sup>b</sup>	468283.13±6474.20 <sup>a</sup>	446076.60±5987.38 <sup>b</sup>	5.301	0.040
Fixed cost (BDT/ha)					
Lease value	101150.00	101150.00	101150.00	-	-
Water (pump)	10000.00	10000.00	10000.00	-	-
Lime	13320.00	13320.00	13320.00	-	-
Fertilizer	22875.00	22875.00	22875.00	-	-
Labour	54000.00	54000.00	54000.00	-	-
Harvest	25000.00	25000.00	25000.00	-	-
Total cost (BDT/ha)	805605.22±1888.19 <sup>ab</sup>	822805.50±6404.43 <sup>a</sup>	800457.59±6246.62 <sup>b</sup>	4.913	0.042
Total return (BDT/ha)	973955.08±7367.12 <sup>ab</sup>	1172753.13±18001.88 <sup>a</sup>	1052451.73±8893.97 <sup>b</sup>	65.751	0.000
Net profit (BDT/ha)	168349.86±5789.13 <sup>c</sup>	349947.63±14691.16 <sup>a</sup>	251994.14±10665.91 <sup>b</sup>	68.252	0.000
CBR	0.21±0.01 <sup>c</sup>	0.42±0.02 <sup>a</sup>	0.31±0.01 <sup>b</sup>	67.463	0.000

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



### Fish growth and yield

Growth performance of fish species are shown in Figure 2. Only the growth performance of surface and column feeder fishes showed significant ( $P<0.05$ ) variations among the treatments. *G. catla* and *H. molitrix* with their combination of 30% as surface feeder at  $T_1$  showed significantly ( $P<0.05$ ) higher final weight, weight gain, SGR and survival rate compared to  $T_2$  and  $T_3$ . On the other hand, *L. rohita* as column feeder with 30% contribution at  $T_2$  showed significantly higher final weight, weight gain, SGR and survival rate compared to  $T_1$  and  $T_3$ . Growth performance of bottom feeder *C. cirrhosus* and *C. carpio* did not vary significantly among the treatments because of their constant contribution of 30% in all the treatments. Decreasing the percentage of surface feeder at  $T_1$  compared to  $T_3$  and  $T_2$  provided much more space and food for fishes, which resulted in better growth performance of fishes at  $T_1$ . Similar observation was also recorded for column feeder *L. rohita*. These findings were in agreement with Mohanty et al. (2004), Rahman and Verdegem (2010) and Mridha et al. (2014), who stated that fishes at high density become subjected to comparatively higher competition for food and space that causes physiological stress to fishes and results in lower growth performance. Effect of stocking size and stocking combination were also evident during the present study. Final weight, weight gain and SGR were higher in the present study compared to Azad et al. (2004), Talukder et al. (2018) and Kabir et al. (2009), whereas they followed irregular stocking combination and smaller initial stocking size for fishes. Higher survival rate of fishes at treatment  $T_1$  for surface feeder fishes and at  $T_2$  for column feeder fish were similar to the finding of Mollah et al. (2011) and Rahman et al. (2015) in earthen ponds, and Moniruzzaman et al. (2015) in floating cages, whereas they also reported higher survivability at lower stocking density. However, survival rate of the fishes during the present study were higher compared to the findings of Talukder et al. (2018), Khan et al. (2018) and Roy et al. (2002) might be due to the improvement of pond environment through good aquaculture practice. Variations in the fish yield under the treatments are shown in Table 3. All the species responded significantly towards the varied combinations of fish species among the treatments. Although individual weight of surface feeders were the highest at  $T_1$  with 30% contribution in overall combination, significantly higher final production was recorded at  $T_2$  whereas their contribution was 40%. Similarly, final yield of column feeder *L. rohita* was significantly higher at  $T_2$  with 30% contribution to total combination. Overall, species combination in carp fattening ponds showed significant difference in total fish yield with the highest yield was obtained from  $T_2$  ( $4192.54 \pm 79.37$  kg/ha/6 months) followed by  $T_3$  ( $3746.98 \pm 33.91$  kg/ha/6 months) and  $T_1$  ( $3451.50 \pm 32.62$  kg/ha/6 months). Therefore,  $T_2$  was 21.47% and 11.89% higher than  $T_1$  and  $T_3$ , respectively. A study conducted by Talukder et al. (2017) in carp polyculture ponds under drought prone *barind* area had reported a fish yield ranging from  $1411.29 \pm 25.19$  to  $3693.23 \pm 69.37$  kg/ha/6 months which was much lower than the present findings. *Barind* tract situated in the northwest part of Bangladesh is characterized by

higher elevation and undulating uplands with red or yellow clay soil, lower rainfall and lower water holding capacity of soil during dry period, which make this area more vulnerable to climate change effect. Therefore, carp polyculture in this area is affected by poor survivability and growth performance of fish species (Hossain, 2011). However, several researchers (Hossain, 2011; Hossain et al., 2009; Hossain, 2007; Hossain and Bhuiyan, 2007) conducted their research to find out proper solution to these problems and recommended some mitigating process such as the use of lime and ash treatment to resolve the problem of low alkalinity and high turbidity, and larger initial stocking size of fishes that would grow faster and reached the marketable size within the period of water holding. However, these mitigation processes cannot reach to the up to mark level and fish productions from carp polyculture pond remained within the range of  $1411.29 \pm 25.19$  to  $3693.23 \pm 69.37$  kg/ha/6 months (Talukder et al., 2017). During the study period, some specific recommendations such as introduction of carp fattening technique, fish culture with appropriate stocking combination and the application of good aquaculture practice from the earlier research had been followed, and therefore, fish production in the present experiment exceeded the findings of other studies.

### Economics of carp fattening

Variation in the mean values of cost, net benefit and CBR are shown in Table 4. Variable cost items (seed and feed cost) were found varied significantly among the treatments. Feed was the major cost involving area (55.00-60.00% of the total cost) with the treatments. Apart from the feed, two other important factors like lease value (12.29-12.64%) and water addition (1.22-1.25% of the total cost) for the ponds was increased the cost of fish production through carp fattening in drought prone *barind* area. Pond lease cost was 68.16% and 36.63% higher than the findings of Mohsin et al. (2012) and Kobir et al. (2017), respectively. Other cost items that increased the overall production cost during the study period were water, lime, fertilizer, labour and harvest cost. Being a *barind* tract area, water cost was a new addition together with extra lease value. Moreover, lime, fertilizer and labour cost were around 47%, 76% and 34%, respectively higher compared to the findings of Khan et al. (2018), who had conducted their study at Sadar upazila of Faridpur district, Bangladesh. Total cost, net benefit and CBR were also varied significantly ( $P<0.05$ ) with the combination of fishes at different treatments. Total cost was ranged between  $800457.59 \pm 6246.62$  BDT/ha/6 months ( $T_3$ ) and  $822805.50 \pm 6404.43$  BDT/ha/6 months ( $T_2$ ), which was again more than 50% higher than the findings of Khan et al. (2018). However, this extra cost had been recovered through fattening and good aquaculture practice followed during the study period, and species combination at  $T_2$  was proved to be more suitable as it provided 51.89% and 27% higher net income compared to the treatment  $T_1$  and  $T_3$ , respectively. Finally, the present experiment was resulted in a higher cost benefit ratio of  $0.42 \pm 0.02$  at  $T_2$  followed by  $0.31 \pm 0.01$  at  $T_3$  and  $0.21 \pm 0.01$  at  $T_1$ .

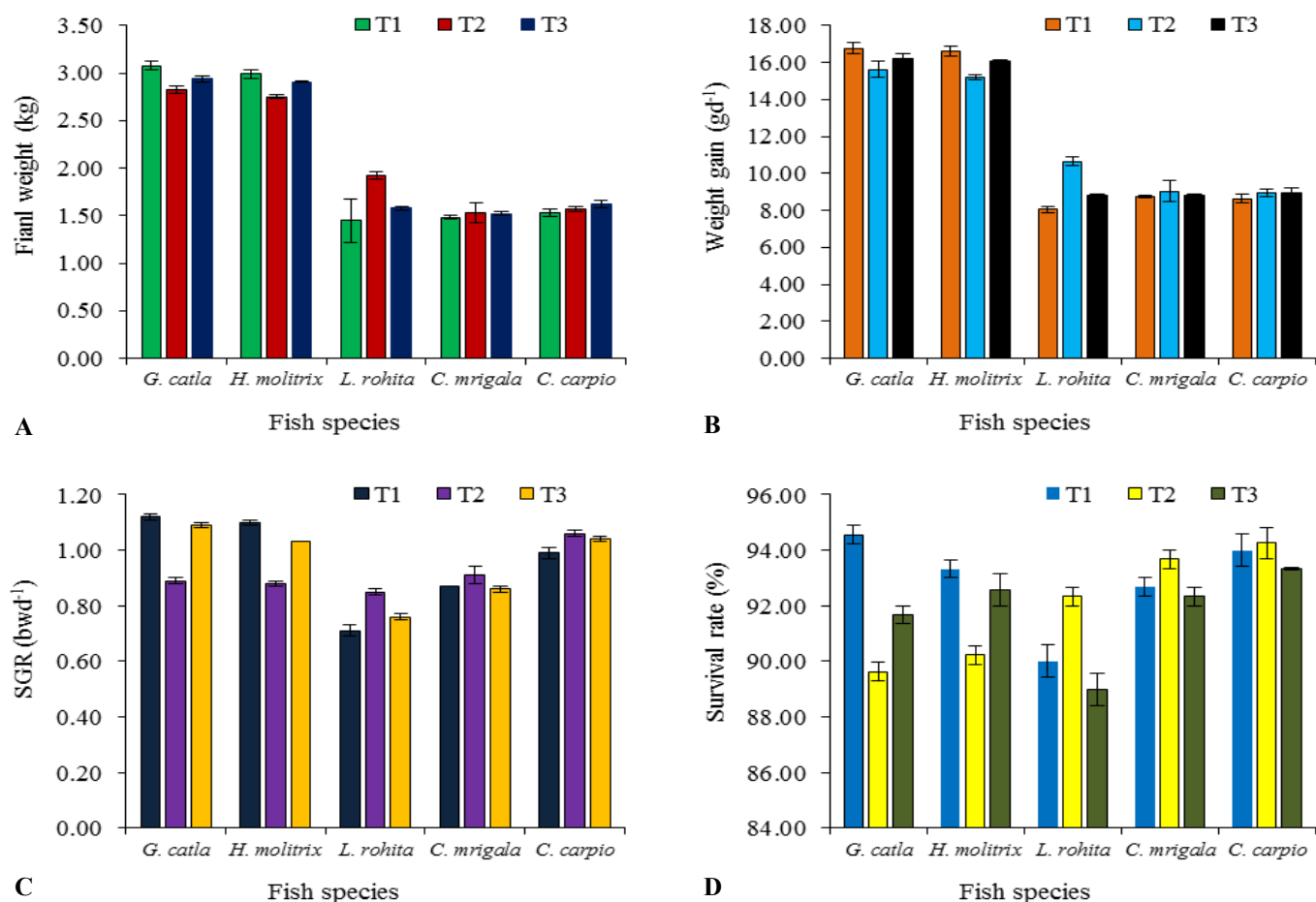


Figure 2. Fish growth performance (final weight-A, daily weight gain-B, SGR-C and survival rate-D) under different treatments of carp fattening.

## Conclusion

The present experiment of the selection of suitable species combination for carp fattening pond indicated that treatment T<sub>2</sub> with a species combination of 40% surface feeder, 30% column feeder and 30% bottom feeder was found best in terms of environmental parameters, growth, production and economic performance in ponds of *barind* tract area. Findings clearly indicated that inclusion of appropriate number of surface feeding carp especially *H. molitrix* favoured the growth of column and bottom feeding carps. Findings also indicated that carp fattening is constrained by high feed cost (more than 50% of the total cost) and high lease value of the ponds (more than 12% of the total cost). Further effort is also required with focus on the optimization of stocking density together with formulation of low cost feed for safe fish production through carp fattening in ponds under *barind* area of Bangladesh.

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