Performances of Bottom Dwelling Carps in Polyculture Ponds under Drought Prone Barind Area of Bangladesh

Abstract
Selection of appropriate bottom dwelling species is considered important to address the problem of increased temperature and reduced culture period for carp polyculture in ponds under drought prone Barind area (with characteristic soil and water quality) in Bangladesh. This experiment evaluated the performances of bottom feeding carps for polyculture ponds in Tomoreupazila of Rajshahi district, Bangladesh. Three different combinations of bottom feeding carps were tested under three treatments (T1: polyculture involving Cyprinus carpio as bottom dwelling carp, T2: polyculture involving Cirrhinus mrigala as bottom dwelling carp; and T3: polyculture involving Labeo calbasu as bottom dwelling carp). Each treatment had three replications. Fish growing period (July-December), mean weight (100±0.4g) and density of the stocked species (Catla catla-741/ha, Hypophthalmichthys molitrix-1,976/ha, Aristichthh is nobilis-741/ha, Labeo rohita-1,976/ha and Cyprinus carpio/Cirrhinus mrigala/Labeo calbasu-1,976/ha; all species-7,410/ha), lime and ash treatment, fertilization and supplementary feeding were same for all treatments. Water quality parameters were monitored monthly and mean values were found within the suitable range. Treatment T1 (with Cirrhinus carpio as bottom dwelling carp) varied more significantly (P<0.05) than other treatments for the mean values of growth (Final weight, weight gain, specific growth rate and survival rate), yield and net benefit.

Keywords: Bottom feeder; Carp polyculture; Drought

Introduction
Importance of pond based carp polyculture as a popular technique for fish production in Bangladesh is well documented [1]. It has further potentials to improve the livelihood of the poor and marginal peoples [2]. Potentials of pond based fish production towards livelihood improvement are also explored well by Hossain et al. [3] for Barind area having characteristic soil-water qualities like lower pH and organic matter content in soil along with lower alkalinity and higher turbidity level in pond water [4]. Apart from these potentials of pond polyculture and constraints for fish production associated with soil-water qualities, promotion of aquaculture is found to be affected by climate change aspects. Studies indicate that climate change may result in decline of groundwater level [5] and thus remodelling of carp polyculture is felt necessary in terms of insufficient water level in ponds under drought prone area. Fish production in polyculture is largely affected by species combination, stocking density, pond fertilization, supplementary feeds as well as ecological conditions. Stocking of comparatively larger size of carps can solve the problem of fish production for lower water column in polyculture ponds under drought prone area [2]. However all species do not play equal role in terms of water quality and fish production. The knowledge of fish-fish and fish-environment relationships enables choosing adequate combinations of fish species, stocking rates, input types and rates, and other management decisions according to the specific local conditions; climate, quality of water supply and pond fertility, availability of fish fry and fingerlings, availability of feeds and fertilizers, and market requirements [6]. Polyculture is the system in which fast growing compatible species of different feeding habits are stocked in different proportions in the same ponds Chakraborty et al., 2005. The bottom dwelling carps help re-suspension of bottom nutrients to water while stirring the bottom mud in search of food. Such an exercise of bottom dwellers also aerates the bottom sediment. Techniques to mitigate the low alkalinity and high turbidity problems are found to be addressed well but guidelines are not found for selecting appropriate bottom dwelling species for profitable carp polyculture in ponds under drought prone area. This study evaluated the performances of bottom dwelling species in carp polyculture ponds under Barind area of northern Bangladesh. The specific objectives of this study were to monitor the water quality and fish growth; to evaluate the yield and economics of carp polyculture; and thereby to recommend best performing species combination for profitable carp polyculture in ponds under drought prone Barind area.

Materials and Methods
Study duration and location
The study was conducted in nine ponds (mean water area of 0.025±0.003 ha and depth of 1.66±0.096 m) for a period of six months (July to December) in Rajshahi district, Bangladesh (24.3545°N, 088.3200°E to 24.3553°N, 088.3222°E; elevation: 21 to 23 m). All the ponds were rain-fed and well exposed to sunlight of average 8 hours per day.

Experimental design
Randomized Completely Block Design (RCBD) was followed for the present experiment with three treatments involving.
of combinations of bottom dwelling species ($T_1$: polyculture involving *Cyprinus carpio* as bottom dwelling carp; $T_2$: polyculture involving *Cirrhinus mrigala* as bottom dwelling carp; and $T_3$: polyculture involving *Labeocalbasu* bottom dwelling carp). Each treatment had three replications. Stocking density (*Catla catla*–741/ha, *Hypophthalmichthys molitrix* –1,976/ha, *Aristichthus nobilis*–741/ha, *Labeo rohita*–1,976/ha and *Cyprinus carpio/Cirrhinus mrigala/Labeocalbasu* –1,976/ha; all species-7,410/ha) and mean individual stocking weight of fish (100±0.4g) were same for all treatments.

**Pond management**

Weeding was done manually and predatory fish and other unwanted species were removed through repeated netting. In order to maintain good water quality, liming (CaO @ 750 kg/ha as basal dose and 125 kg/ha/month as periodic dose) with urea (Basal dose: 50 kg/ha; periodic dose: 50 kg/ha/month) and TSP, Triple Super Phosphate (Basal dose: 50 kg/ha; periodic dose: 25 kg/ha/month). Basal fertilization was done after three days of liming. Selected species of carp fingerlings were purchased from a private nursery and stocked in the morning (Table 1 & 2).

**Table 1:** Experimental layout for carp polyculture in ponds under different treatments.

| Parameters | Treatments and Replications |
|------------|----------------------------|
| Replications | $T_1$: Pond stocked $C. carpio$ as bottom feeder | $T_2$: Pond stocked with $C. mrigala$ as bottom feeder | $T_3$: Pond stocked with $L. calbasu$ as bottom feeder |
| --- | --- | --- | --- |
| Pond area (ha) | $R_1$ | $R_2$ | $R_3$ | $R_1$ | $R_2$ | $R_3$ | $R_1$ | $R_2$ | $R_3$ |
| 0.022 | 0.025 | 0.021 | 0.027 | 0.025 | 0.030 | 0.025 | 0.023 | 0.028 |
| Pond depth (m) | 1.60 | 1.55 | 1.65 | 1.80 | 1.73 | 1.68 | 1.50 | 1.65 | 1.75 |
| Total fish stocked | 163 | 185 | 156 | 200 | 185 | 222 | 185 | 170 | 207 |

**Table 2:** Variations in the mean values of water quality parameters under different treatments during the study period.

| Parameters | Treatments | $T_1$ | $T_2$ | $T_3$ | $F$ value | $P$ value |
|------------|------------|-------|-------|-------|-----------|-----------|
| Water temperature (°C) | 27.61±0.99 | 27.31±1.04 | 27.19±1.00 | 0.042 | 0.959 |
| Dissolved oxygen (mgL\(^{-1}\)) | 6.76±0.23 | 6.74±0.22 | 6.71±0.24 | 0.011 | 0.990 |
| Turbidity (cm) | 28.81±0.45 | 28.62±0.59 | 28.57±0.55 | 0.056 | 0.945 |
| pH | 7.12±0.08 | 7.10±0.08 | 7.19±0.07 | 0.413 | 0.664 |
| Alkalinity (mgL\(^{-1}\)) | 61.43±1.76 | 60.24±1.87 | 60.48±1.69 | 0.126 | 0.882 |

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

**Monitoring of water quality parameters**

Water quality parameters like temperature, transparency, dissolved oxygen (DO), pH, and alkalinity were monitored monthly between 09:00 and 10:00 AM for the present study. Water temperature was recorded with the help of a Celsius thermometer, transparency was measured by a Secchi disk. Dissolved oxygen (DO), pH and alkalinity were determined by the help of a HACH kit (FF-2, USA).

**Determination of fish growth and yield**

Fish growth was monitored by weighing at least 10% of the individual species caught from each pond using a cast net, and sampled fishes were released into the ponds unharmed immediately after sampling. Growth and yield of fishes were calculated after Brett and Groves (1979) as follows:

\[
\text{Specific Growth Rate: SGR (\%, bwd\(^{-1}\))} = \frac{[\ln W_2 - \ln W_1] \times 100}{(t_2 - t_1)}
\]

Where, $W_1$ and $W_2$ are the mean start and end weight (g fish\(^{-1}\))

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and \( t_1 \) and \( t_2 \) (days) are the start and end of the period.

\[
\text{Survival rate (%) = (Number of fish harvested / Number of fish stocked) } \times 100
\]

Fish yield (kg ha\(^{-1}\)) = Fish biomass at harvest – Fish biomass at stock

**Economics of Carp Polyculture**

Simple cost-benefit analysis was done to explore the economics of carp polyculture in ponds 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 Rajshahi, Bangladesh in 2012 and were expressed in Bangladesh currency (Taka) as BDT (1 US $=80 BDT). Data on both fixed and variable costs were recorded to determine the total cost (BDT/ha). Total return determined from the market price of fish sale was expressed as BDT/ha. Net benefit and cost benefit ratio (CBR) were calculated as follows:

\[
R = I - (Fc + Vc + Ii)
\]

Where, \( R \) refers to net benefit; \( I \), total income from fish sold; \( Fc \) for fixed costs, \( Vc \) for variable costs and \( Ii \) for interests on input costs.

\[
\text{Cost – Benefit Ratio (CBR) = } \frac{\text{Net benefit}}{\text{Total Investment}}
\]

**Statistical Analysis**

Before analysis, the normality of data were verified and then analyzed by one-way ANOVA using SPSS software version 16). Different treatments were compared. The mean values were also compared by Duncan Multiple Range Test (DMRT) after Gomez and Gomez (1984) at 5% level of significance. All data were expressed as mean ± standard error (S.E.).

**Results**

**Water quality**

The ANOVA and Duncan’s test showed that there was no significant (\( P <0.05 \)) difference of mean value of water quality parameters among the treatments (Table 3 & Figure 1). Mean value of water temperature (°C), dissolved oxygen (mgL\(^{-1}\)), transparency (cm), pH and total alkalinity (mgL\(^{-1}\)) varied from 27.19±1.00 (T\(_3\)) to 27.60±0.99 (T\(_1\)), 6.71±0.24 (T\(_3\)) to 6.76±0.23 (T\(_1\)), 28.57±0.55 (T\(_3\)) to 28.81±0.45 (T\(_1\)), 7.10±0.08 (T\(_2\)) to 7.19±0.07 (T\(_3\)) and 60.24±1.87 (T\(_2\)) to 61.43±1.76 mgL\(^{-1}\) (T\(_1\)), respectively.

**Table 3: Growth and yield of fishes under different treatments.**

| Species             | Treatments | SGR (% bwd\(^{-1}\)) | Weight Gain (g) | Final Weight (g) | Survival Rate (%) |
|---------------------|------------|-----------------------|-----------------|-----------------|------------------|
| *Labeorohita*       | T\(_1\)    | 0.88±0.01\(^a\)       | 66.67±0.96\(^a\) | 500.00±5.7\(^a\) | 85.50±0.87\(^a\) |
|                     | T\(_2\)    | 0.85±0.02\(^a\)       | 61.67±2.55\(^a\) | 470.67±15.26\(^a\) | 86.50±0.29\(^a\) |
|                     | T\(_3\)    | 0.85±0.02\(^a\)       | 65.00±2.93\(^a\) | 490.00±17.56\(^a\) | 85.33±10.44\(^a\) |
| *Catlacatla*        | T\(_1\)    | 0.94±0.01\(^a\)       | 75.83±2.21\(^a\) | 555.00±13.\(^a\) | 86.33±0.44\(^a\) |
|                     | T\(_2\)    | 0.92±0.02\(^a\)       | 73.33±2.41\(^a\) | 540.00±14.43\(^a\) | 87.17±0.44\(^a\) |
|                     | T\(_3\)    | 0.90±0.02\(^a\)       | 70.00±2.55\(^a\) | 490.00±17.56\(^a\) | 86.50±0.29\(^a\) |
| *Hypothalmichthys molitrix* | T\(_1\)    | 1.09±0.02\(^a\)       | 105.00±4.19\(^a\) | 730.00±25.\(^a\) | 85.33±0.60\(^a\) |
|                     | T\(_2\)    | 1.07±0.02\(^a\)       | 102.50±3.63\(^a\) | 715.00±21.79\(^a\) | 86.67±0.93\(^a\) |
|                     | T\(_3\)    | 1.04±0.03\(^a\)       | 95.83±5.20\(^a\)  | 675.00±31.23\(^a\) | 86.83±0.67\(^a\) |
| *Aristichthis nobilis* | T\(_1\)    | 1.11±0.02\(^a\)       | 111.67±4.41\(^a\) | 770.00±26.46\(^a\) | 85.67±0.44\(^a\) |
|                     | T\(_2\)    | 1.09±0.02\(^a\)       | 106.67±3.85\(^a\) | 740.00±23.09\(^a\) | 87.17±0.73\(^a\) |
|                     | T\(_3\)    | 1.07±0.01\(^a\)       | 102.50±2.10\(^a\) | 715.00±12.58\(^a\) | 85.50±0.29\(^a\) |
| *F value*           |            | 1.527                 | 1.500           | 1.500           | 1.235           |
| *P value*           |            | 0.291                 | 0.296           | 0.296           | 0.355           |
| *Hypothalmichthys molitrix* | T\(_1\)    | 1.164                 | 1.164           | 1.164           | 1.217           |
|                     | T\(_2\)    | 0.374                 | 0.374           | 0.374           | 0.360           |
| *F value*           |            | 1.644                 | 1.635           | 1.635           | 3.138           |

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Fish growth

Results showed no significant (P <0.05) differences in the mean value of SGR, weight gain and final weight for all fish species except C. carpio (T₁), C. mrigala (T₂), and L. calbasu (T₃). Duncan’s test revealed that mean value of SGR, final weight and weight gain in treatment T₁ (with C. carpio as bottom feeder) was significantly (P <0.05) higher compared to T₂ and T₃, where C. mrigala and L. calbasu were stocked as bottom feeders, respectively. The examined treatments were statistically similar in the estimation of survival rates for all fish species under three treatments (Table 4).

Table 4: Fish yield (kg/ha/6 months) under the treatments.

| Species       | Treatments | F value | P value |
|---------------|------------|---------|---------|
|               | T₁         | T₂      | T₃      |
| L. rohita     | 675.69±8.70 | 632.55±27.82 | 657.83±32.20 | 0.747 | 0.513 |
| C. catla      | 291.16±9.87 | 284.11±7.92 | 269.27±10.66 | 1.368 | 0.324 |
| H. molitrix   | 1062.40±44.19 | 1052.99±35.59 | 986.01±48.44 | 0.935 | 0.443 |
| A. nobilis    | 425.22±15.65 | 413.23±13.24 | 389.63±7.93 | 2.011 | 0.215 |
| C. carpio     | 1083.93±61.10 | 780.78±39.56 | 2986.77±94.89 | 22.621 | 0.001 |
| C. mrigala    | 780.78±39.56 | 684.04±19.73 | 2986.77±94.89 | 22.621 | 0.001 |
| L. calbasu    | 684.04±19.73 | 2986.77±94.89 | 22.621 | 0.001 |
| All species   | 3538.41±64.17 | 3163.66±22.12 | 2986.77±94.89 | 17.484 | 0.003 |

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

The present study revealed significant (P < 0.05) difference in the yield under different treatments with highest in \( T_1 \) and lowest in \( T_3 \). The study also revealed that the mean value of yield for \( C. \) carpio (\( T_1 \)), \( C. \) mrigala (\( T_2 \)) and \( L. \) calbasu (\( T_3 \)) were significantly different, whereas mean value of yield of other fish species were statistically similar (Table 5 & Figure 2).

Table 5: Economics of carp polyculture under different treatments.

| Treatments                | Treatments (mean value in BDT/ha/6 months) | F Value | P value |
|---------------------------|--------------------------------------------|---------|---------|
| Parameters                | \( T_1 \)                                  | \( T_2 \)          | \( T_3 \)          |       |       |
| Variable Costs            |                                            |         |         |       |       |
| Pond preparation\*        | 9000.00±0.00\( ^a \)                      | 9000.00±0.00\( ^a \) | 9000.00±0.00\( ^a \) | -     | -     |
| Fertilizer                | 17500.00±0.00\( ^a \)                      | 17500.00±0.00\( ^a \) | 17500.00±0.00\( ^a \) | -     | -     |
| Fish seed                 | 90400±11.25\( ^c \)                        | 95000±8.25\( ^a \) | 96250±14.23\( ^a \) | -     | -     |
| Feed                      | 110150.00±563.00\( ^c \)                   | 112330.00±0.00\( ^a \) | 115715±0.00\( ^a \) | 239.958 | 0.000 |
| Harvesting cost           | 2000.00±0.00\( ^a \)                       | 2000.00±0.00\( ^a \) | 2000.00±0.00\( ^a \) | -     | -     |
| Fixed Costs               |                                            |         |         |       |       |
| Pond Rental               | 1500.00±0.00\( ^a \)                       | 1500.00±0.00\( ^a \) | 1500.00±0.00\( ^a \) | -     | -     |
| Total cost                | 230550.00±0.00\( ^a \)                     | 237330.00±944.39\( ^a \) | 241965.00±0.00\( ^a \) | 678.183 | 0.000 |
| Total return              | 530252.32±8232.07\( ^a \)                  | 478623.03±3274.96\( ^a \) | 466219.40±12414.15\( ^a \) | 43.874  | 0.001 |
| Net benefit               | 299702.32±8232.07\( ^a \)                  | 241293.01±3274.96\( ^a \) | 224254.40±10093.24\( ^a \) | 23.563  | 0.001 |
| Cost Benefit Ratio (CBR)  | 1.30±0.036\( ^a \)                         | 1.02±0.114\( ^a \) | 0.93±0.040\( ^a \) | 37.234  | 0.000 |

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

Note: Currency is given in Bangladeshi Taka (BDT); (80 BDT = 1 USD, 2012)

* includes lime, ash and labor cost

Discussion

Water quality

Lower temperature recorded in the later stage of the study might be gradual approach to the winter that might have impact on the seasonal variation of the water quality [7]. Lower value of water transparency found in all treatments might be due to higher clay turbidity caused by heavy rainfall in monsoon. Periodic application of ash minimized high turbidity during the high rainy season. Hossain [4] reported high turbidity during monsoon and followed ash treatment to maintain suitable water turbidity. Saran & Rathore [8,9] stated lower transparency due to rich phytoplankton density and higher budgets of suspended and particulate matter. Boyd [10] recommended 30 to 40 cm
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transparency appropriate for fish culture. Similar to the current results, Dewan & Swingle [11,12] recorded mean pH value of water from 6.60 to 6.80 and 6.5 to 9, respectively. Boyd [10] suggested over 20 ppm, and Michael & Verma [13,14] suggested over 40 ppm total alkalinity for productive pond that aligned with present results. However, Asadujjaman and Hossain [4] recorded relatively higher total alkalinity (113.28 to 114.36 mg/L) in feed and weed-based pond polyculture that might be due to low dissolved oxygen and more production of free CO₂ that enhanced by increasing fish biomass.

However, above findings indicated that the mean value of the water quality parameters in the present study were within the suitable range for aquaculture. The findings from recent studies also supported the above statement. Talukder et al. [2] found water temperature 26.57 to 26.68°C, dissolved oxygen 6.81 to 6.86 mg/L, water transparency 29.90 to 30.17 cm, pH 6.88 to 6.96 and alkalinity 51.29 to 52.26 mg/L in carp polyculture ponds. Asaduzzaman et al. [15] reported water temperature, dissolved oxygen, transparency, pH and total alkalinity as 27.57 to 28.13°C, 6.51 to 6.73 mg/L, 32.83 to 33.28 cm, 7.38 to 7.18, 61.51 to 63.17 mg/L. Ahmad et al. reported temperature from 27.08 to 28.66°C, DO from 5.15 to 5.91 mg/L, transparency from 18.17 to 25.50 cm and pH from 8.04 to 8.23 in polyculture pond. The mean water temperature, pH, DO, CO₂ and total alkalinity was recorded as 19.6 to 32°C, 6.6 to 8.1, 1.1 to 4.9 mg/L, 3.5 to 4.0 mg/L and 92.0 to 167. mg/L respectively in polyculture pond [16]. Hossain et al. [17] recorded dissolved oxygen ranging from 5.33 to 5.51 mg/L.

Fish growth

Significant (P <0.05) differences in mean values of fish growth parameters were found among the treatments (Table 4). However, variations in growth might be due to the different combination of fish species under treatments.

Comparatively higher mean value of SGR, final weight, weight gain indicated the positive influence of C. carpio as bottom feeder on overall growth parameters compared to C. mirgala and L calbasu in carp polyculture. Rahman et al. [18] recorded mean SGR of rohu, catla and mrigal as 1.12, 1.09 and 1.13 to 1.13, 1.12 and 1.14 respectively in different treatments under pond polyculture system. Majhi et al. [19] recorded SGR value of carp as 1.65% in fish pond. Hossain [4] found weight gain of L. rohita, C. catla, C. mrigala, H. moliitrix, A. nobilis and C. carpio as 125.7, 170.2, 120.8, 40.0, 420, 400, 400 respectively with stocking weight of 7.5 to 10.0 g in polyculture under Barind area which were lower than the findings from present study. Comparatively higher mean monthly weight gain (g/month) was observed at mid time of the study might be due to influence of air temperature on water temperature resulting fast metabolic activity and thereby higher weight gain of fishes at the mid-stage of the experiment. Boyd [20] expressed similar opinion while working on pond carp polyculture.

No significant (P <0.05) variations in survival rate (%) under different treatments possibly due to similar stocking weight and stocking density of fishes including similar feed and management of all ponds. Talukder et al. [2] reported similar survival rates (83.17±0.58, 84.13±0.58, 85.33±0.58, 84.13±1.00, 85.33±0.58, 84.42±0.66%) for L. rohita, C. catla, C. mrigala, H. moliitrix and A. nobilis, respectively in carp polyculture ponds. Asadujjaman and Hossain [15] recorded similar range of survival rate (%) of L. rohita, C. catla, C. mrigala, H. molitrix and C. idella. Kabir & Talukdar et al. [3,21] recorded survival rate of C. carpio from 83.2 to 86% and 82%, respectively in carp polyculture system. Roy et al. [22] reported survival rate (%) of grass carp, rohu, catla and mrigal 76.6%, 87.8%, 84.0% and 88.6%, respectively, which are likely findings of present study.

Azad et al. [23] reported weight gain of H. molitrix as 72.87 g and C. mirgala as 70.42 g in carp polyculture ponds which were lower than the present findings. Kabir et al. [3] found final weight (g/6 months) of H. molitrix, C. mirgala and C. carpio as 300, 210 and 211.20 g respectively which were lower than the present findings. Higher final weight (g/6 months) achieved in the present study might be due to optimum species composition, larger stocking weight and better management of water quality, proper utilization of both natural and supplementary feeds.

Fish yield

Yield significantly (P <0.05) varied among all three treatments. The study revealed that the combined yield of L. rohita, C. catla, H. molitrix and A. nobilis under three treatments were not significantly varied; but yield significant (P <0.05) varied in case of three different bottom feeders e.g. C. carpio: 1083.93±61.09 kg/ha/6 months (T₁), C. mrigala: 780.78±39.562 kg/ha/6 months (T₂), and L. calbasu: 684.04±19.733 kg/ha/6 months (T₃) respectively. That might be due to difference in first growing nature of three bottom feeders as well as effects of combination of other fish species. Yield of C. carpio was found significantly high compared to other two bottom feeders which finally contributed to overall variation in net yield.

Siddiquei [24] reported that the gross fish production of 40.4 kg/dec/yr from mixed culture which is a bit higher than the present findings. Noman et al. [25] reported that comparatively higher yield and net benefit were observed when C. carpio was used in carp polyculture. Net yield of the present study was higher in T₂ compared to T₁ and T₃, might be due to first growing nature of C. carpio and larger stocking weight with better pond management and suitable range of water quality parameters. Asadujjaman & Hossain [15] recorded total yield of 4,403.51 kg/ha/6 months with conventional feed applied and lower production of 2,541.00 kg/ha/6 months where only banana leaf was supplied. Mijaje [26] reported the total production of fish from 2,934 to 3,318 kg/ha/4 months in polyculture of Indian major carps which was similar to the findings from present study. Azim et al. [27] recorded total fish yield of 2,020 kg/ha/4 months in pond which was lower than the findings from the present study possibly due to higher stocking weight in present study. Such variations in growth and yield among the treatments were the usual phenomenon of fish growth form which was strongly supported by Grover et al. [28].

Economics

Economic analysis of current study showed significant (P <0.05) variations in total cost, return, net benefit and CBR among treatments (Table 5 & Figure 3). Comparatively higher cost was involved in treatment T₃ might be due to the higher fish seed cost for L. calbasu compared to C. carpio (T₂) and C. mrigala (T₃).

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Figure 3: Variation in the mean values of CBR under different treatments.

Talukder et al. [2] recorded total cost and net benefits as 253,768.00±5146.04 and 337,629.45±7295.36 BDT/ha/6 months, respectively and cost benefit ratio as 1.33. Asadujjaman & Hossain [15] recorded 123,430.50±0.00 to 205,930.50±0.00 BDT/ha/6 months; net benefit as 111,699.90±2056.87 to 206,744.85±5221.73 BDT/ha/6 months; and cost benefit ratio as 0.77±0.02 to 1.67±0.18, respectively in carp polyculture system. Khan et al. [29] reported CBR value of 1.22 in pond polyculture system; and Abou et al. [30] found CBR as 1.3 in carp polyculture system which was similar to the present findings.

Overall findings from the current study revealed that treatment T1 with C. carpio as bottom feeder performed better in terms of total cost, net benefit and CBR compared to treatment T2 and T3 stocked with C. mrigala and L. calbasu, respectively. Milstein et. al. [6] certify C. carpio as a first growing and high tolerant to environmental hazards.

According to Jain C. carpio has the ability to survive under various climatic conditions and found to be the most suitable for many fish farming systems. Da Silva et al. concluded that C. carpio has the potential to improve conditions in pond bottom soil, as a result soil perturbation increases the oxygen transfer to the soil, decreases the concentration of toxic compounds and enables more efficient food web recycling and nutrient release [31-38].

Conclusion and Recommendation

Considering the water quality, growth and yield of fish and economic viability of carp polyculture in pond under three treatments, treatment it can be concluded that stocking of C. carpio as bottom dwelling species can be a suitable option for carp polyculture in ponds under drought prone Barind area. One of the major limitations of this study was to use equal stocking density of all three bottom dwelling species. Therefore, it is necessary to see the effect of different stocking density of C. carpio as bottom dwelling species in carp polyculture as further step.

Acknowledgment

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Conflict of Interest

None.

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