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# Growth, Yield and Profitability of Major Carps Culture in Coastal Homestead Ponds Stocked with Wild and Hatchery Fish Seed

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**Abstract:** Major carps, native freshwater fish in South Asian nations, are economically valuable fish species with high market demand. Coastal rural people can cultivate them in their own seasonal, largely underutilized, small homestead ponds with low input and understanding. However, the major problems with fish production in this region are the lack of quality carp seed and appropriate culture techniques. Therefore, this research was carried out on growth performance, survival rate, yield, feed conversion ratio (FCR), and profit of carp polyculture systems stocking with hatchery-produced and wild sourced fish seed in homestead ponds located in a coastal area along the Bay of Bengal. Three different treatments (T1–T3), each treatment with three replications, were designed for culturing carps, *Gibelion catla*, *Labeo rohita*, *Labeo calbasu*, and *Cirrhinus mrigala* using two local hatcheries seeds (T1 and T2), and wild seeds from the Halda River (T3). For all treatments, the stocked fish were maintained in the same size, weight, density, and ratio. Water quality parameters were measured at intervals of seven days, and the mean values were found to be within an acceptable range for fish farming and, in most cases, did not differ significantly from each other. The specific growth rate (SGR) was found higher in T3 for *G. catla* (1.16 ± 0.012%/day), *L. rohita* (1.19 ± 0.035%/day), and *C. mrigala* (1.06 ± 0.03%/day) and significantly differed ($p < 0.05$) among the treatments. Additionally, there were significant differences between the treatments in terms of ultimate weight, weight gain, survival rate, fish production, and return on investment (ROI) ($p < 0.05$). The lower FCR in T3 (2.65 ± 0.10) than in T1 (3.32 ± 0.31) and T2 (3.21 ± 0.33) indicated that stocking wild seed had higher profitability potentials. High genetic variety in the population of naturally occurring, free-living fish, resistance to disease, a high rate of survival, and the hardiness of wild seed are all factors that might contribute to the better performance of wild seed stock. However, the total yield and total return from the T3 treatment also emphasized that carp farming using wild seed is not viable because of the variable amount, high seed cost, low transportation facilities, and very small natural seed-stock supplies from the river. Inbreeding and reduced genetic variety in the hatchery stock could result in the production of poor-quality seed, which had an impact on the production performance in culture treatments stocked with hatchery seed.

**Keywords:** carp polyculture; homestead ponds; wild and hatchery source; growth; yield

## 1. Introduction

In Bangladesh, carp polyculture is a widely used fish culture system based on the idea of fully using all of a pond's trophic and spatial niches to enhance fish production [1].

Stocking suitable fish species of different feeding habits (herbivores, carnivores, and omnivores) and layers (surface, middle, and bottom) in various pond cultures composed through the highest utilization of entirely natural food resources and spaces is the fundamental technique of carp polyculture [2]. The potential for increasing fish development through carp polyculture has been established to its fullest extent in conjunction with additional procedures [3]. In the last 10 years, Bangladesh's aquaculture production has nearly doubled because of increased research and expansion initiatives, with just carp accounting for 45.35% of the total fish produced in pond aquaculture [4]. Additionally, there are some problems with the development of aquaculture in Bangladesh's carp polyculture system. The scarcity of high-quality fish seed is the biggest barrier to boosting fish production in this country [5]. Poor inbreeding, hybridization, bloodstocks, and unfavorable selection management are the main causes of poor performance in fish seed [6]. The use of high-quality seed could increase yield by up to 30% while maintaining the same level of management [7]. Factors such as brood feeding, pond fertilization, and water quality affect the quality of the broods and seed; however, if a method lowers the genetic variety of the broods, it cannot be rectified, but the protein and pond maintenance qualities are enhanced.

Pond culture is the foundation of aquaculture, making up about 55% of all controlled culture practices worldwide in 2014–2015 and roughly 80% of all documented manufacturers in Bangladesh [8]. Homestead ponds and commercial aquaculture are included in pond aquaculture. The latter captures around half of all aquaculture productivity that has been documented [9]. The contribution of Indian major carps (IMCs) to Bangladesh's overall pond fish production is 31.74% (4.67 lakh MT) [10]. Homestead pond aquaculture in Bangladesh, which employs over four million people and covers an area of 266,259 ha in 2010, is the predominant method of aquaculture [11]. Homestead ponds play a significant role in domestic revenue generation and fish consumption, accounting for 3 to 15% of total household income and 25% to 50% of all fish production [11]. Together, the homestead ponds provide a fantastic chance for women to dominate and contribute to aquaculture, from which they are ordinarily excluded because of social and cultural restrictions, and because they are divided from the residents of the homestead ponds. In contrast, there are other aspects of fisheries and fish culture [12]. The most popular fish species produced in household pond polyculture practices are bighead carp (*Hypopthalmichthys nobilis*), catla (*Geblion catla*), common carp (*Cyprinus carpio*), mrigal (*Cirrhinus cirrhosis*), rohu (*Labeo rohita*), and silver carp (*Hypophthalmichthys molitrix*) [13,14].

In Bangladesh, freshwater pond fish culture systems are mostly extensive or semi-intensive, with only a few cases being intensive. During a semi-intensive culture practice, the ponds are stocked primarily with Indian major carps and exotic carps; fertilizer (primarily trash, urea, and TSP) is used irregularly; and supplementary feed consists of rice-bran and oilcake. Aquatic animals are raised using traditional methods and natural feed, with little to no fertilizer use. The fish that are stocked are not specifically chosen, the predator is not eliminated, and the complete assembly cycle is not handled or fertilized. The use of both detailed intensive and semi-intensive systems is not distinguished by the general fish culture in Bangladesh.

Noakhali is located in the middle coastal zone of Bangladesh toward the north-eastern coast of the Bay of Bengal. This district has the presence of many ponds, canals, floodplains, and the locality of the area to the Meghna River estuary certifies the consequence of the district in total fish culture and capture fish of the country. The total area of the pond in Bangladesh is estimated at 305,025 hectares (ha), of which 90.77% is agricultural, 7.82% is cultivable, and 1.42% is derelict. In Noakhali, the total cultivable pond area is 12,322 ha, of which 9857 ha are planted, 2218 ha are cultivable, and 247 ha are derelict [15]. Nearly every home in these coastal neighborhoods has a small pond next to the backyard, which is utilized for domestic activities rather than for fish farming. These small homestead ponds, which are seasonal and can only hold water for a few months, can be used to raise fast-growing fish, such as carp, to meet their nutritional needs and generate income.

Fish farmers rely more on wild seed for fish culturing in ponds at a lower cost and high return because of the deliberately planned growth proportions of hatchery seed [16]. Therefore, a total of 3326 kg of seed were gathered from the river basin in 2012–2013 [9] compared to 4819 kg in 2015–2016 [4]. Extensive use of wild seed by fish farmers clearly points to the necessity of finding the easiest reproducing species to supply common seed sources through the proper enhancement of the broodstock. There are four main varieties of Indian carp stock found in this subcontinent: Brahmaputra-Jamuna stock, Barak-Meghna stock, Ganga-Padma stock, and Halda stock [17]. Among them, Halda stock is considered one of the best quality seed stocks because of its genetic purity and diversity. The goals of this study were to assess the overall productivity, yield, and cost-benefit analysis of carp polyculture in homestead ponds stocked with wild and hatchery seed, and to identify the best-performing quality seed sources to maximize profitable carp polyculture in homestead ponds, which can enhance the standard of living for rural coastal residents.

## 2. Material and Methods

### *2.1. Experimental Design*

This study was performed on the growth performance and fish yield of Indian major carps stocking with seed from two local renowned hatcheries (T1 and T2), and natural (Halda River-T3) sources in homestead ponds of Noakhali district, Bangladesh. Mentionable, hatcheries use fresh water for breeding purposes, and the salinity in the Halda River (wild stock) ranges from 45.4 ppm to 15.7 ppm. The research was designed following the Randomized Completely Block Design (RCBD) procedure and the work of Khan et al. (2018), with some modifications (Figure 1). The seed from three different sources (one wild and two hatchery sources) were stocked into three ponds (blocks) with three replications (termed T1R1, T1R2, T1R3; T2R1, T2R2, T2R3; T3R1, T3R2, T3R3). The culture period was for 6 months, starting from July 2020 December 2020, as local homestead ponds retain water only for 4–6 months. To design the experiment, local polyculture practice, indigenous knowledge, and geographical and climatic conditions of the Noakhlai floodplain were considered. As the homestead ponds of Noakhali are seasonal and rain-fed, we have adapted our experimental design according to the local tradition of polyculture so that local farmers can adopt it. Four species of carps viz. *Gibelion catla*, *Labeo rohita*, *Cirrhinus cirrhosus*, and *Labeo calbasu* were used as experimental species and stocked with a similar density (370 kg fish seed per hectare) in nine earthen ponds. All ponds are rectangular in size (16.1 m $\times$ 10.8 m) with a depth of 1.5 m. The ponds were supplied separately with freshwater from an adjacent deep tube well and were completely exposed to an average of 8 h a day of sunshine. The mean stocking weights of *G. catla*, *L. rohita*, *C. mrigala*, and *L. calbasu* were 134.93 $\pm$ 3.85 g, 115.85 $\pm$ 5.02 g, 119.09 $\pm$ 1.27 g, and 118.17 $\pm$ 1.62 g, respectively.

### *2.2. Pond Preparation and Fish Seed Stocking*

Before adding the fish, all aquatic weeds in the ponds were carefully removed. By adopting repeated netting, undesirable aquatic species and other species were eliminated. To maintain acceptable water quality, liming (CaO at a rate of 247 kg/ha as a basal dose and 120 kg/ha/month as a periodic dose) was also carried out. Cow dung was used to boost the production of natural feed after three days of liming (baseline dose: 2470 kg/ha; periodic dose: 1235 kg/ha/month). In addition, urea (basal dose, 50 kg/ha; periodic dose, 25 kg/ha/month) and Triple Super Phosphate (TSP; baseline dose, 50 kg/ha; periodic dose, 25 kg/ha/month) were applied, as recommended by Karim and Rahman [18]. After 10 days of fertilization, the fish were stocked in the early hours (5–9 a.m.).

### *2.3. Feeding Management*

Feeding started right away once the pond was stocked with seed. Two times each day (at 8:00 a.m. and 5:00 p.m.), additional feed with a 30% dietary protein content was applied, consisting of a mixture of 25% rice bran, 25% wheat bran, 25% fish meal, and 25% mustard oil cake. For the first month, supplementary feeding was done at 6% of fish body weight; for the following three months, it was at 5%; and for the final two months, it was at 2%. As part of the monitoring of fish growth, the amount of feed was modified monthly in accordance with the total biomass of the fish determined through sampling.

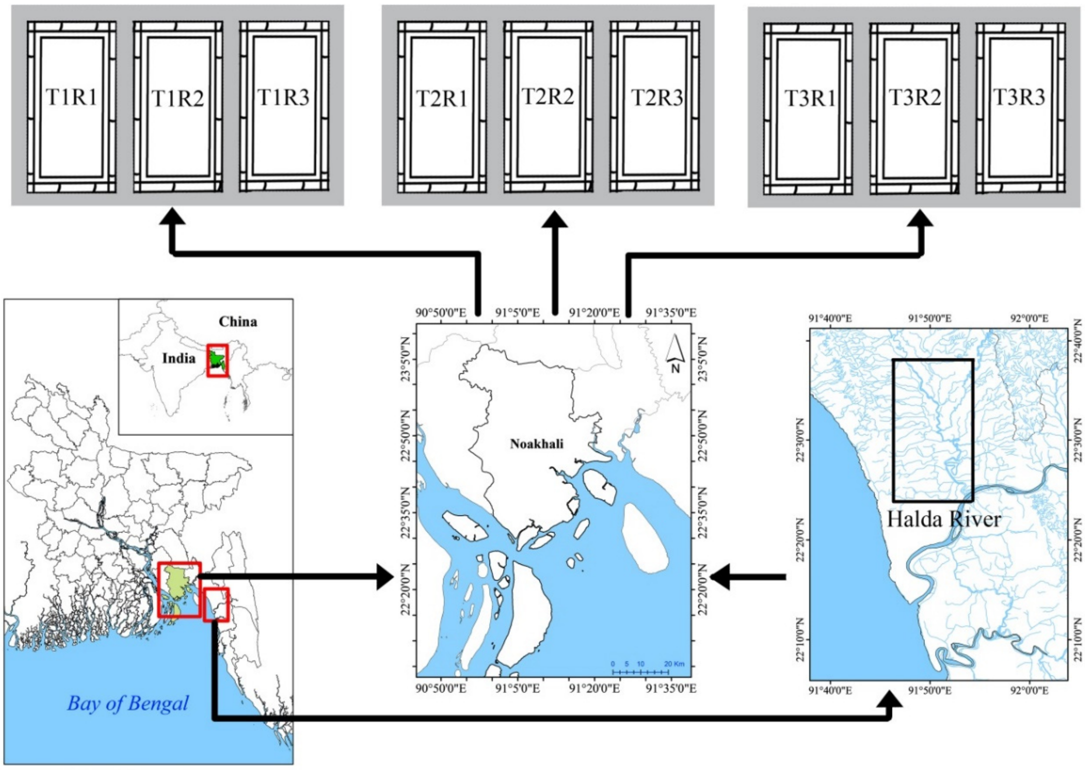


**Figure 1.** Location of study site and sampling design.

## *2.4. Water Parameter Monitoring*

Key water quality parameters viz., pH, temperature (°C), dissolved oxygen (mg/L), salinity (PSU), TDS (mg/L), and conductivity (µS/cm) were determined and recorded every seven-day interval between 9.00 and 10.00 a.m. by means of Hannah Multi-parameters (Model: H198194). To account for sunlight penetration, a Secchi disc was also used to measure water transparency (cm).

## *2.5. Assessment of Fish Growth Performances and Yields*

To check the health and growth of fish, 10% of stocked fish from each experimental pond were sampled using a cast net at monthly intervals. The specific growth rate (SGR), survival rate, feed conversion ratio (FCR), gross yield (GY), net yield (NY), and coefficient of variation (CV) were measured at the end of the experimental period, following the equation:

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

$$\text{Weight gain (\%)} = [\text{Final weight (g)} - \text{Initial weight (g)}/\text{Initial weight}] \times 100$$

$$\text{SGR (\%/day)} = [ln\ \text{(Final weight)} - ln\ \text{(Initial weight)}]/\text{Experimental period in days}] \times 100$$

$$\text{FCR} = [\text{Feed given (dry weight)}/\text{Body weight gain (wet weight)}]$$

$$\text{Net yield (kg ha}^{-1}) = \text{Fish biomass at harvest} - \text{Fish biomass at initial stocking}$$

## *2.6. Economics of Carp Culture*

A cost-benefit (CBA) analysis was conducted alongside the economics of carp culture to compare the various treatments. Ultimately, the study harvested fish and sold them to nearby farmers' markets. The CBA of the various methods was estimated based on variable costs (cost of lime, organic and inorganic fertilizers, seed of fish, and feed) and income from fish sales. Prices are represented in Bangladesh's currency (BDT). The volume of total return computed from fish purchase prices was reported as BDT/ha. The price and fish inputs approached the 2020 wholesale market rates in Noakhali, Bangladesh. The estimate of the net profit and cost–benefit ratio (CBR) was as follows:

$$R = I - Vc$$

where, R notice to net benefit; I, total income from fish sold, and Vc for variable costs.

$$CBR = \text{Net benefit}/\text{total investment}$$

*2.7. Statistical Analysis*

Using Microsoft Excel 2016 and PAST (Paleontological Statistics; Version 4.03, Palaeontological Association, Oslo, Norway) statistical software, measured data on water quality parameters, fish growth rate, yield, and economics of carp polyculture under different treatments were subjected to a one-way analysis of variance (ANOVA). All information was presented as the mean standard deviation (SD). With a level of significance of 0.05, the significant difference between the mean values of the treatments was compared.

## 3. Results and Discussion

*3.1. Water Quality Parameters*

The water quality variables recorded from the three treatments are presented in Table 1. The values of water pH, salinity, DO, transparency, temperature, TDS, and conductivity among the treatments ranged from 7.72 ± 0.29 to 7.87 ± 0.20, 0.15 ± 0.02 PSU to 0.16 ± 0.05 PSU, 5.11 ± 0.20 mg/L to 5.2 ± 0.18 mg/L, 30.16 ± 2.29 cm to 32.96 ± 2.06 cm, 23.68 ± 2.52 °C to 23.86 ± 2.87 °C, 285.15 ± 21.74 to 306.53 ± 36.02, and 570.38 ± 43.42 to 613.17 ± 72.06, respectively, which were more or less similar to the findings of previous studies [2,6,19–21]. Significant differences were noticed in some parameters (pH and transparency) among the treatments (Table 1). However, the findings of water quality parameter values were found within the standard range for carp fish farming, for example, 6–9 (pH), 4–8 mg/L (DO), 25–40 cm (transparency), 10–35 °C (temperature) [22,23]. The salinity values were quite low, as the source of water in the culture system was mainly rain and groundwater. Major carps can tolerate a maximum salinity level of 9 PSU without any physiological stress. However, the optimum salinity for major carp culture is 0–5 PSU.

*3.2. Fish Growth and Survival Rate Assessment*

Significant differences ($p < 0.05$) were observed among the carp polyculture treatments from various seed sources in terms of weight gain, final weight, and SGR (Table 2). The variation in the weight of the harvested fish from different treatments was influenced by the availability of food, species strains, frequency of feeding, and the collaborations among species [24]. However, maximum SGR was documented in T3 in *G. catla* (1.16 ± 0.012%/day), *L rohita* (1.19 ± 0.035%/day), and *C. mrigala* (1.06 ± 0.03%/day) except *L. calbasu* where lower SGR (1.00 ± 0.02) was recorded in T3. The highest weight gain and survival rate were also recorded in T3 (Table 2), indicating that fish seed from natural sources had a higher growth rate with survival capacity. The survival rate (%) for *G. catla and L. calbasu* followed the same decreasing order: T3 > T2 > T1 and for *L. rohita* and *C. mrigala,* it was T3 > T1 > T2. Overall, the highest survival rate (>90%) was observed in T3 for all species, and the survival rate was significantly varied for *G. catla and L. calbau* in T3 and T1 but not for *L rohita* and *C. mrigala.* Mamun and Mahmud [6] reported that the survival rates of *G. catla*, *L. rohita*, *C. mrigala,* and *G. catla* were 80%, 85.42%, and 81%, respectively, which were more or less similar to the present study. Further, the mean SGRs of *G. catla, L. rohita*, and *C. mrigala* were recorded as 1.14 ± 0.32, 0.95 ± 0.26, and 1.05 ± 0.25, respectively, in the carp polyculture pond [1], which also supported our findings. However, there is very limited information comparing the culture performance and profitability of wild sources seed and hatchery sources seed of carp polyculture. According to Khan et al. [2], carp seed from wild sources perform better than hatchery-sourced seed in terms of growth, adult size, and survival in polyculture environments. However, our findings were comparable to some earlier studies that focused on the effects of feeding frequencies, stocking density, introduction of native carp, environmental variables, and culture management [25–31]. For example, Azad et al. [31] reported that the mean survival rate for major carps in earthen ponds ranged from 90.63 to 91.10%. They also recorded higher growth performance with low stocking density in the polyculture system.

**Table 1.** Descriptive statistics of water quality parameters observed in the three different treatments (mean ± SD; range in parentheses).

| Parameter | Unit | Treatments | | | F | *p* Value |
|---|---|---|---|---|---|---|
| | | T1 | T2 | T3 | | |
| pH | - | 7.98 ± 0.26 $^{a}$ (7.3–8.35) | 7.72 ± 0.29 $^{b}$ (7.2–8.3) | 7.87 ± 0.20 $^{c}$ (7.3–8.21) | 9.68 | 0.00013 |
| Salinity | PSU | 0.15 ± 0.04 $^{a}$ (0.08–0.24) | 0.16 ± 0.05 $^{a}$ (0.07–0.29) | 0.15 ± 0.02 $^{a}$ (0.10–0.25) | 0.929 | 0.397 |
| DO | mg/L | 5.12 ± 0.24 $^{ab}$ (4.69–5.61) | 5.11 ± 0.20 $^{a}$ (4.7–5.56) | 5.20 ± 0.18 $^{b}$ (4.90–5.59) | 2.093 | 0.13 |
| Transparency | cm | 30.16 ± 2.29 $^{a}$ (25.5–33.2) | 32.96 ± 2.06 $^{a}$ (28.5–35.5) | 30.76 ± 2.04 $^{a}$ (25.9–33.8) | 18.53 | <0.001 |
| Water temperature | °C | 23.68 ± 2.52 $^{a}$ (18.2–26.1) | 23.86 ± 2.87 $^{a}$ (18.4–26.55) | 23.68 ± 2.80 $^{a}$ (18.5–26.7) | 0.05 | 0.94 |
| TDS | mg/L | 285.15 ± 21.74 $^{a}$ (244–333) | 299.10 ± 28.30 $^{b}$ (256–353) | 306.53 ± 36.02 $^{b}$ (260–400) | 5.36 | 0.005 |
| Conductivity | µS/cm | 570.38 ± 43.42 $^{a}$ (488–666) | 598.30 ± 56.60 $^{b}$ (512–706) | 613.17 ± 72.06 $^{b}$ (520–800) | 5.37 | 0.005 |

Figures bearing common letters (a, b, c) in a row as superscripts do not differ significantly ($p < 0.05$).

**Table 2.** Growth and production of fish under three different treatments.

| Species | Treatment | Number of sp./Ha | Average Initial Weight (g) | Average Final Weight (g) | SGR (%/day) | Weight Gain (g) | Survival Rate (%) |
|---|---|---|---|---|---|---|---|
| *Gibelion catla* | T1 | 878 | 130.49 ± 7.31 $^{a}$ | 889.23 ± 62.39 $^{a}$ | 1.06 ± 0.011 $^{a}$ | 758.74 ± 55.56 $^{a}$ | 77.78 ± 6.93 $^{a}$ |
| | T2 | 870 | 136.88 ± 5.55 $^{a}$ | 10,096.14 ± 27.9 $^{b}$ | 1.11 ± 0.01 $^{b}$ | 872.26 ± 23.14 $^{b}$ | 82.78 ± 2.54 $^{a}$ |
| | T3 | 823 | 137.40 ± 0.76 $^{a}$ | 1117.92 ± 41.16 $^{c}$ | 1.16 ± 0.012 $^{c}$ | 980.51 ± 40.42 $^{c}$ | 90.11 ± 4.83 $^{a}$ |
| | F | - | 1.57 | 18.5 | 45.21 | 21.05 | 4.44 |
| | *p* | - | 0.28 | 0.002 | <0.001 | 0.001 | 0.06 |
| *Labeo rohita* | T1 | 888 | 110.79 ± 1.30 $^{a}$ | 804.21 ± 7.58 $^{a}$ | 1.10 ± 0.01 $^{a}$ | 693.42 ± 7.67 $^{a}$ | 75.11 ± 8.33 $^{a}$ |
| | T2 | 823 | 120.83 ± 1.93 $^{b}$ | 956.49 ± 12.42 $^{b}$ | 1.15 ± 0.01 $^{b}$ | 835.66 ± 13.40 $^{a}$ | 74.11 ± 12.27 $^{ab}$ |
| | T3 | 823 | 115.93 ± 1.01 $^{c}$ | 1039.94 ± 17.09 $^{c}$ | 1.19 ± 0.035 $^{b}$ | 924.01 ± 18.08 $^{a}$ | 91.44 ± 4.07 $^{b}$ |
| | F | - | 34.88 | 255 | 14.67 | 215.4 | 3.60 |
| | *p* | - | <0.001 | <0.001 | 0.005 | <0.001 | 0.09 |
| *Cirrhinus mrigala* | T1 | 660 | 120.46 ± 3.04 $^{a}$ | 665.10 ± 13.16 $^{a}$ | 0.95 ± 0.04 $^{a}$ | 544.63 ± 11.16 $^{a}$ | 74.50 ± 5.77 $^{a}$ |
| | T2 | 658 | 117.95 ± 1.98 $^{a}$ | 643.19 ± 6.16 $^{a}$ | 0.96 ± 0.02 $^{a}$ | 525.24 ± 8.06 $^{a}$ | 72.91 ± 8.99 $^{a}$ |
| | T3 | 659 | 118.85 ± 1.04 $^{a}$ | 766.04 ± 14.34 $^{a}$ | 1.06 ± 0.03 $^{b}$ | 647.19 ± 13.33 $^{b}$ | 92.85 ± 6.90 $^{b}$ |
| | F | - | 1.02 | 92.64 | 12.62 | 105.2 | 6.82 |
| | *p* | - | 0.41 | <0.001 | 0.007 | <0.001 | 0.03 |
| *Labeo calbasu* | T1 | 658 | 116.39 ± 3.35 $^{a}$ | 701.87 ± 15.20 $^{a}$ | 1.07 ± 0.01 $^{a}$ | 585.48 ± 12.38 $^{a}$ | 77.78 ± 2.67 $^{a}$ |
| | T2 | 660 | 118.55 ± 2.31 $^{a}$ | 758.61 ± 14.43 $^{b}$ | 1.03 ± 0.02 $^{b}$ | 640.06 ± 13.48 $^{b}$ | 86.81 ± 7.87 $^{ab}$ |
| | T3 | 658 | 119.56 ± 0.65 $^{a}$ | 806.72 ± 6.95 $^{c}$ | 1.00 ± 0.02 $^{b}$ | 687.15 ± 7.60 $^{c}$ | 94.77 ± 2.34 $^{b}$ |
| | F | - | 1.38 | 50.8 | 17.65 | 59.27 | 8.71 |
| | *p* | - | 0.31 | <0.001 | 0.003 | <0.001 | 0.01 |

Figures bearing common letter (a, b, c) in a column as superscript do not differ significantly ($p < 0.05$).

### *3.3. Fish Yield and Feed Conversion Ratio (FCR)*

The yield of *L. rohita* and *L. calbasu* differed considerably ($p < 0.05$) among the three treatments, although *G. catla* and *C. mrigala* did not significantly differ among the treatments

(Table 3). In contrast, the Halda River seed sources (T3) had a lower FCR (2.65 ± 0.10) than the other seed sources. Again, the variance was not significant ($p > 0.05$) between T1 (3.32 ± 0.31) and T2 (3.21 ± 0.33), but both treatments significantly differed from T3. The overall fish yield also differed considerably ($p < 0.05$), from 1686.36 ± 129.92 kg/ha/6 months in T3 to 1376.78 ± 112.64 kg/ha/6 months in T1. The increased production of natural seed supplies also indicates that this species is better able to withstand stressors than seed from hatcheries, such as low dissolved oxygen or disease. In addition, growth and yield have medium to high heritability for some native Indian major carp species, indicating that a large-scale selection program for these species could achieve improvements in culture efficiency [32]. In Bangladesh, the traditional carp polyculture technique produces fish at a rate of 3119 to 4067 kg/ha per year [21,33,34]. The farming of the main carp species from wild sources produced a higher net profit and return on investment, even though seed from wild sources was more expensive than seed from hatchery sources (ROI). This was substantially related to the higher yield (kg/ha) and higher percentage of large-sized main carps in the polyculture population of carps than in the population of hatchery sources. The amount of feed and seed for the carp polyculture varied among the three treatments, which affected expenses. The culture of native large carp from wild sources required less feed input per kg of adult fish than the culture of seed from hatchery sources because the seed from wild sources had a lower FCR than the seed from hatchery sources.

**Table 3.** Observation of fish yield and FCR in three different treatments.

| Species | Fish Yield (kg/ha/6 Month) | | | F | *p* Value |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | | |
| *Gibelion catla* | 352.35 ± 151.90 $^{a}$ | 598.77 ± 67.84 $^{a}$ | 559.65 ± 86.28 $^{a}$ | 4.49 | 0.06 |
| *Labeo rohita* | 468.20 ± 67.24 $^{a}$ | 478.65 ± 94.24 $^{ab}$ | 589.77 ± 12.07 $^{b}$ | 3.01 | 0.12 |
| *Cirrhinus mrigala* | 149.41 ± 91.26 $^{a}$ | 169.12 ± 57.21 $^{a}$ | 217.03 ± 78.37 $^{a}$ | 0.61 | 0.57 |
| *Labeo calbasu* | 205.60 ± 61.81 $^{a}$ | 338.29 ± 69.66 $^{ab}$ | 319.90 ± 3.86 $^{b}$ | 5.35 | 0.05 |
| All species | 1376.78 ± 112.64 $^{a}$ | 1584.85 ± 126.53 $^{ab}$ | 1686.36 ± 129.92 $^{b}$ | 4.91 | 0.05 |
| FCR | 3.32 ± 0.31 $^{a}$ | 3.21 ± 0.33 $^{a}$ | 2.65 ± 0.10 $^{b}$ | 5.35 | 0.04 |

Letters with common letter(s) in a row as superscript do not differ significantly ($p < 0.05$).

### *3.4. Economics of Carp Polyculture*

The average total cost differed from 296,762.5 ± 17,686.14 (≈3169.87 ± 188.94 USD) (T2) to 311,968 ± 16,702.94 (≈3332.44 ± 178.41 USD) (T3) BDT/ha/6 month. The net half yearly total return (BDT/ha) and net benefit significantly ($p < 0.05$) varied from 351,213 ± 24,592.93 (T1) to 410,427.2 ± 26,042.5 (T3) and 54,083.56 ± 13,919.48 (T1) to 98,459.23 ± 21,000.62 (T3), respectively (Table 4). The CBR among the treatments varied from 0.14 ± 0.12 (T1) to 0.22 ± 0.19 (T2). The overall cost and CBR were reported to range from 123,430.5 to 235,930.5, 235,068.4 to 418,376.85, 11,1639.90 to 206,744.85, and 0.77 to 1.67 in the three treatments, respectively, in a carp polyculture system [1]. Total cost was found to be slightly higher in treatment T3 than T1, and T2, but net benefit and CBR were found to be highest in treatment T3. Such variation in growth and yield with carp polyculture from various sources (hatchery and wild) may be attributable to the well-known phenomena of high-quality seed sources with rich genetic diversity in the wild. However, there was no discernible difference in CBR between T1, T2 (supplied with seed from hatcheries), and T3 (stocked with seed from the Halda River). With such variations between hatchery-produced seed and wild seed, it may be possible for the quality deterioration of the seed produced in hatcheries. The high genetic diversity, high rate of survival, and readily adaptive nature of wild seed stock might be the main reasons for the high performance. In contrast, the low genetic diversity and survival rate and delicate nature of hatchery seed might be the reasons for comparatively low production. Generally, in captive conditions, fish exhibit changed behavior due to a stressful environment. This may have an impact on their reproductive capacity and physiological activities, resulting in poor-quality eggs and seed. In the hatchery, producing seed often entails using a small number of brood stocks with a low population number and extensive inbreeding. According to some estimates, the majority of hatchery operators' breeding practices result in inbreeding rates of 3–5% per generation [14]. In a hatchery, when female and male breeders are selected from a small population and there is a higher risk of sibling or close relatives crossing, inbreeding is likely to occur. Inbreeding can be reduced, and genetic variety can be increased by collecting wild germplasm, using carefully thought-out selective breeding programs, and line crossing. This genetic intervention can enhance qualities such as genetic variety, growth rate, survival, and disease/stress tolerance, which will ultimately result in the production of high-quality seed stock. Additionally, the genetic variation among the breeders used in the hatchery and genotype–environment interaction could be the reason for such variations, which needs further study. Such studies are lacking now in the study area. One study by Hussain and Mazid [14] from the northern side of the country stressed that hatchery seed are of genetically poor quality. Furthermore, the current results were in line with Shah's findings [16], who observed that hatchery-produced seed grew at a relatively slower rate than seed obtained from wild sources, and with Biswasi et al. [5], who reported that carp seed obtained from the Halda River performed better in polyculture than hatchery-produced seed.

**Table 4.** Economics of different treatments.

| Parameters | Treatment | | | F | $p$ Value |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | | |
| Cost | | | | | |
| Lime | 6000 $^{a}$ | 6000 $^{a}$ | 6000 $^{a}$ | – | – |
| Fertilizer | 4000 $^{a}$ | 4000 $^{a}$ | 4000 $^{a}$ | – | – |
| Fish seed | 102,393.6 ± 3150.18 $^{a}$ | 101,928 ± 3076.04 $^{a}$ | 117,133.5 ± 121.25 $^{b}$ | 34.69 | <0.001 |
| Feed | 185,674.7 ± 13,881.67 $^{a}$ | 189,371.4 ± 12,389.97 $^{a}$ | 187,030.2 ± 9953.30 $^{a}$ | 0.07 | 0.93 |
| Total cost | 297,228. ± 19,700.81 $^{a}$ | 296,762.5 ± 17626.14 $^{a}$ | 311,968 ± 16,702.94 $^{a}$ | 0.69 | 0.54 |
| Return | | | | | |
| Total return | 351,312 ± 24,592.93 $^{a}$ | 392,028.3 ± 27,161.81 $^{ab}$ | 410,427.2 ± 26,042.5 $^{b}$ | 4.07 | 0.07 |
| Net benefit | 54,083.56 ± 13,919.48 $^{a}$ | 94,965.82 ± 10,557.14 $^{b}$ | 98,459.23 ± 21,000.62 $^{b}$ | 7.34 | 0.02 |
| Cost-benefit ratio | 0.14 ± 0.12 $^{a}$ | 0.22 ± 0.19 $^{a}$ | 0.2 ± 0.17 $^{a}$ | 0.16 | 0.85 |

Figures bearing common letter (a, b) in a row as superscript do not differ significantly ($p < 0.05$).

## 4. Conclusions

The results of this study indicated that the wild-sourced carp polyculture was more productive than that of seed produced from hatchery. The better performances of wild seed stock can be attributed to high genetic diversity in the free-living natural fish population, disease resilience, a high rate of survivability, and the hardy nature of wild seed. On the other hand, comparatively low productivity in hatchery seed stock can be due to reduced genetic variation, introgressed hybridization, inbreeding among the breeders used in the hatchery, and genotype–environment interaction, which needs further investigation, as such studies are lacking in the study area. When kept in a hatchery, fish, or breeders exhibit altered behavior due to the stressful environment in which they are subjected. This could have an impact on the brooders' reproductive and physiological health, and ultimately the quality of their eggs and offspring. The growth and yield output of large native carps such as *G. catla*, *L. rohita*, *C. mrigala*, and *L. calbasu* of the Halda Rivers are considered higher than local hatcheries, respectively. However, because of the variable quantity, high seed, and transportation cost, and restricted natural seedstock resources of carps in the Halda River, reliance on obtaining wild seed is not a sustainable practice. As a result, the use of wild germplasm, well-planned selective breeding, and line crossing through genetic intervention can increase the genetic variation and reduce the inbreeding problem in the fish hatcheries in Bangladesh. Further studies on these aspects are recommended, as they are beyond the scope of this research.

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