Journal of Fisheries
Volume 6 Issue 1 Pages 541–548 April 2018
Peer Reviewed | Open Access | Online First

eISSN 2311-3111
pISSN 2311-729X

DOI: https://doi.org/10.17017/j.fish.33

Original Article

Production and economics of carp polyculture in ponds stocked with wild and hatchery produced seeds

Md. Rafiqual Islam Khan[1] • Md. Taskin Parvez[1] • Mohammad Golam Sarowar Talukder[1]
Md. Akhtar Hossain[1] • Md. Shamsul Karim[2]

[1] *Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh.*
[2] *Department of Fisheries (DoF), Ministry of Fisheries and Livestock, Bangladesh.*

Correspondence
Prof Dr Md. Akhtar Hossain; Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh.
mahfaa@yahoo.com

Manuscript history
Received 4 August 2017 | Revised 27 December 2017 | Accepted 6 January 2018 | Published online 9 January 2018

Citation
Khan MRI, Parvez MT, Talukder MGS, Hossain MA and Karim MS (2018) Production and economics of carp polyculture in ponds stocked with wild and hatchery produced seeds. Journal of Fisheries 6(1): 541–548. DOI: 10.17017/j.fish.33

Abstract
Lack of quality carp seeds is one of the major problems for fish production in Bangladesh. This experiment was conducted during July to December 2013 to study the production and economics of carp polyculture using wild and hatchery produced seeds in ponds in Faridpur district, Bangladesh. Seeds of native major carps (NMCs) (*Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*) and non-native carps (NNCs) (*Hypophthalmichthys molitrix*, *Ctenophryngodon idella*, *Aristichthys nobilis* and *Cyprinus carpio*) from four different sources were tested in feed and fertilizer based polyculture ponds under controlled mesocosm trials with four treatments (T_1–T_4), each with four replications. Combination, weight and density of the stocked species were same for all the treatments. Water quality parameters were monitored monthly and mean values were found within suitable range for fish farming. Mean final weight, weight gain, specific growth rate and yield of *L. rohita*, *C. catla* and *C. mrigala* were found significantly ($P < 0.05$) higher with treatment T_1, T_3 and T_2 respectively. Treatments T_1, T_2 and T_3 varied more significantly ($P < 0.05$) than treatment T_4 for total fish yield and cost benefit ratio. Polyculture of wild sourced NMCs and hatchery produced NNCs were found more profitable than aquaculture of hatchery produced NMCs and NNCs.

Keywords: Pond aquaculture; polyculture; native carps; non-native carps; hatchery seeds; wild seeds

1 | INTRODUCTION

Importance of carp polyculture to improve the fish production in Bangladesh is well documented (e.g. Azim and Wahab 2003; Hossain and Bhuiyan 2007; Asadujjaman and Hossain 2016). The basic principle of fish polyculture system depends on the idea as compatible species of different feeding habits are cultured together in the same pond, the maximum utilization of all natural food sources takes place without harmful effects. The possibilities of increasing fish production through carp polyculture are found highest when compared with other systems (Talukdar *et al.* 2012). Due to the progress in research and extension activities, aquaculture production in Bangladesh became almost double in last ten years and carp alone contributed 45.35% of total fish production in ponds (DoF 2017). Also there are some constraints for the promotion of aquaculture in Bangladesh. One of the major constraints to increase fish production in Bangladesh is the non-availability of quality fish seed (Biswas *et al.* 2008). Poor quality fish seed production is largely related to poor management of brood stocks, inbreeding, hybridization and negative selection (Mamun and Mahamud 2014). Keeping all other management same, use of quality seed could increase production even more than 30% (Barman *et al.* 2012). Brood nutrition, pond fertilization, water quality etc. affect brood and seed quality, however, the process that hinders the genetic quality of the broods, if occurs, cannot be overcome, even if nutrition and pond management qualities are enhanced.

Hatchery seeds have significantly slower rates of growth (Shah 2010) and therefore, farmers are depending more on wild seeds for making profitable fish farming in ponds. The amount of spawn collection from rivers was 3326 kg in 2012–13 (DoF 2014) and that of 4819 kg in 2015–16 (DoF 2017). The situation clearly indicates the necessity of identifying the best performing species to supply the quality seeds through proper development of the brood stock. There are four natural Indian major carp strain stocks in our Indian subcontinents- Halda stock, Brahmaputra-Jamuna stock, Ganga-Padma stock and Barak-Meghna stock (DoF 2012). Most of the research efforts on carp polyculture in ponds were carried out using hatchery produced carp seeds, no comprehensive research is done with attention on seed from different sources, water quality, species etc. This study aimed at evaluating the production and economics of carp polyculture in ponds stocked with wild (Padma, Jamuna and Halda rivers) and hatchery produced seeds. The specific objectives of this study were to monitor the water quality and fish growth; to evaluate yield and economics of carp polyculture, and thereby to recommend best performing seed sources for profitable carp polyculture in ponds.

2 | METHODOLOGY

2.1 | Location and duration of study

This experiment was carried out at Sadar upazila of Faridpur district, Bangladesh (23°55′89″N 89°84′59″E – 23°62′94″N 89°86′17″E; elevation, 14 – 22 m) for a period of six months from July to December 2013 in farmer managed earthen ponds (mean [± SD] area, 0.24 ± 0.02 ha; depth, 0.17 ± 0.12 m). All the ponds were rectangular in shape, rain-fed, perennial and well exposed (approximately six to eight hours) to sunlight.

2.2 | Experimental structure

The experiment was designed under Randomized Completely Block Design (RCBD) with four different treatments ($T_1 – T_4$) of varying sources (Padma River, Jamuna River, Halda River and hatchery) of fish seeds (native major carps [NMCs]: *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*; non-native carps [NNCs]: *Hypophthalmichthys molitrix*, *Ctenophryngodon idella*, *Aristichthys nobilis* and *Cyprinus carpio*), each with four replications ($R_1 – R_4$; Table 1). Total density (6916 individuals ha^{-1}) and mean stocking weight of fishes (*C. catla*, 168.25 ± 8.29 – 174.75 ± 3.71 g; *H. molitrix*, 105.5 ± 1.85 – 107.25 ± 2.95 g; *A. nobilis*, 104 ± 2.74 – 106 ± 1.18 g; *L. rohta*, 74.75 ± 1.25 – 75.75 ± 1.8 g; *C. mrigala*, 64 ± 4.45 – 68 ± 3.34 g; *C. carpio*, 58.25 ± 4.45 – 65.75 ± 6.76 g and *C. idella*, 102.75 ± 0.95 – 104.25 ± 2.84 g) were same for all the treatments. Species combination (surface feeders [*C. catla*, *H. molitrix* and *A. nobilis*], 42%; column feeder [*L. rohita*], 29%; bottom feeders [*C. mrigala* and *C. carpio*], 25%; all layer species [*C. idella*], 4%) were also similar in all the treatments.

TABLE 1 Layout of the experiment

Treatments & replications	*Pond area (ha)*	*Water depth (m)*	*Total fish stocked*	*Seed sources*
T_1R_1	0.24	1.9	1660	Padma NMCs + Hatchery NNCs
T_1R_2	0.2	1.6	1383	
T_1R_3	0.2	1.5	1383	
T_1R_4	0.28	2	1936	
T_2R_1	0.2	1.4	1383	Jamuna NMCs + Hatchery NNCs
T_2R_2	0.36	1.6	2490	
T_2R_3	0.2	1.9	1383	
T_2R_4	0.24	1.4	1660	
T_3R_1	0.22	2	1522	Halda NMCs + Hatchery NNCs
T_3R_2	0.2	1.4	1383	
T_3R_3	0.24	1.5	1660	
T_3R_4	0.3	1.7	2075	
T_4R_1	0.2	2	1383	Hatchery NMCs & NNCs
T_4R_2	0.24	1.7	1660	
T_4R_3	0.18	1.9	1245	
T_4R_4	0.24	1.7	1660	

2.3 | Collection of fish seeds

The wild or natural spawns of NMCs were directly collected from six spots of the three rivers (two spots in each river)- Padma (Sardha, 24°16'47.9"N 88°44'14.0"E; Boalia, 24°21'29.9"N 88°36'50.8"E), Jamuna (Fulchari Ghat, 25°18'44.3"N 89°37'19.0"E; Nakalia, 24°02'05.3"N 89°38'58.9"E) and Halda (Modunaghat, 22°25'59.8"N 91°52'23.8"E; Aunkurighona, 22°31'11.5"N 91°50'54.8"E) (Figure 1). The spawns of both NMCs and NNCs were also collected from Indrozit hatchery - a certified fish hatchery in Faridpur district, Bangladesh. Spawns were collected between June and July of the year 2012 and were subjected to nursery rearing for 35 days in farmer managed ponds followed by grow-out rearing before experimental trial under similar density and feeding.

2.4 | Pond preparation and stocking

Aquatic weeds form all the ponds were removed manually before experiment. Unwanted fishes and other species were removed through repeated netting (seine net, mesh size of 12.5 mm). Besides, liming (CaO at the rate of 247 kg ha^{-1} as basal dose and 120 kg ha^{-1} month^{-1} as periodic dose) was done to maintain good water quality. To enhance the natural feed production, fertilization was also done by cowdung (basal dose, 2470 kg ha^{-1}; periodic dose, 1235 kg ha^{-1} month^{-1}), urea (basal dose, 50 kg ha^{-1}; periodic dose, 25 kg ha^{-1} month^{-1}) and Triple Super Phosphate (TSP; basal dose, 50 kg ha^{-1}; periodic dose, 25 kg ha^{-1} month^{-1}). Basal fertilization was done after three days of liming. Both liming and fertilization doses were maintained after Karim and Rahman (2013). All the carp fingerlings were shifted from nursery rearing to farmer managed grow out ponds for stocking. The stocking was done early in the morning.

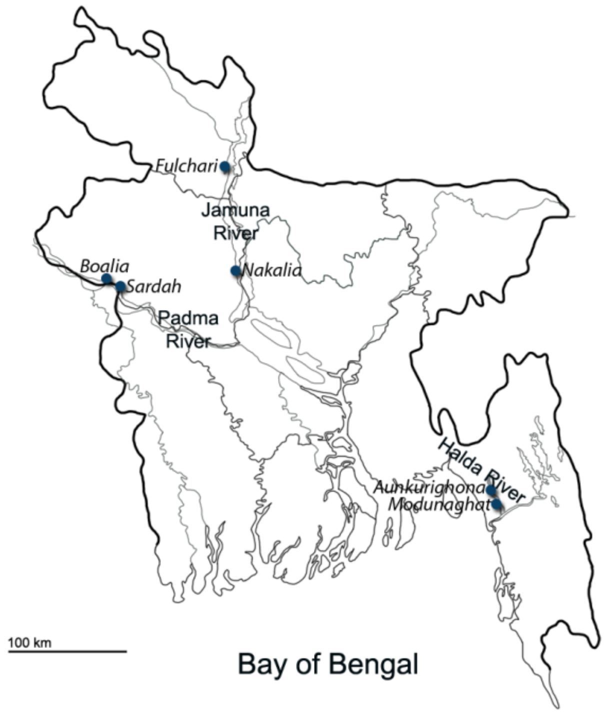

FIGURE 1 Map of Bangladesh showing the natural spawn of NNCs collection sites

2.5 | Supplementary feeding

Supplementary feed (dietary protein content of 24.25%) was used once daily between 9:00 and 11:00 AM with a mixture of rice bran (25%), wheat bran (25%), fish meal (25%) and mustard oil cake (25%). Supplementary feeding was done at the rate of 4.5% of fish body weight (6% for the first month, 5% for the next three months and 2% for the last two months). The quantity of feed was adjusted every month according to total biomass of fish obtained from the sampling as part of monitoring fish growth.

2.6 | Water quality monitoring

Important water quality parameters- water temperature, water transparency, pH, dissolved oxygen (DO), free carbon dioxide (CO_2), alkalinity and ammonia-nitrogen of water were monitored monthly between 8.00 and 10.00 am in the morning. A centigrade thermometer within the range of 0–120 °C was used to record the water temperature. Water transparency (cm) was recorded using a Secchi disk. pH of pond water was recorded with the help of a pH meter (YSI Model 60/10FT, USA). Dissolved oxygen content (mg L^{-1}) of the pond water was recorded with the help of a dissolved oxygen meter (YSI MODEL 58, USA). Digital titration by the help of a HACH kit (FF-2, USA) was followed in determining the free carbon dioxide (mg L^{-1}), alkalinity (mg L^{-1}) and ammonia-nitrogen (mg L^{-1}) of pond water.

2.7 | Fish growth monitoring and yield

Monthly sampling was done for fish growth monitoring. In each sampling, 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. Once the sampling was completed, fishes were subjected to release into the ponds without any harm. Several parameters were used to monitor growth of fishes after Brett and Groves (1979) as follows:

Initial weight (g) = Weight of fish at stock

Final weight (g) = Weight of fish at harvest

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

Specific Growth Rate (SGR [%, bw d^{-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}) and t_1 and t_2 (days) are the start and end of the period.

Survival rate (%) = $\frac{Number\ of\ fish\ harvested}{Number\ of\ fish\ stocked} \times 100$

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

2.8 | Economics of carp polyculture

A simple cost-benefit analysis was followed to explore the economics of carp polyculture under different treatments. At the end of the study, fishes were harvested and sold to local market. 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). Prices of inputs and fish corresponded to wholesale market prices in 2013 of Faridpur, Bangladesh. 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.

$$\text{Cost-Benefit Ratio (CBR)} = \frac{Net\ benefit}{Total\ investment}$$

2.9 | Data analysis

Data on water quality parameters, fish growth and yield, and economics of carp polyculture under different treatments were subjected to one way Analysis of Variance (ANOVA) using SPSS (Statistical Package for the Social Sciences, version 15). Before analysis, the normality of data was checked. The mean values were also compared by Duncan Multiple Range Test (DMRT; Gomez and Gomez 1984) with an α level of significance of 0.05. All data were expressed as mean ± standard error (SE).

3 | RESULT AND DISCUSSION

3.1 | Water quality

Treatments had no significant effect on the water quality parameters (Table 2). The mean values of water temperature, transparency, pH, DO, free CO_2, total alkalinity and ammonia-nitrogen varied from 26.58 ± 0.97 – 26.75 ± 1.08 °C, 35 ± 0.83 – 37.17 ± 0.86 cm, 7.38 ± 0.11 – 7.57 ± 0.1, 5.3 ± 0.13 – 85.5 ± 0.46 mg L^{-1}, 4.92 ± 0.17 – 5.58 ± 0.12 mg L^{-1}, 99.96 ± 4.71 – 110.38 ± 6.21 mg L^{-1} and 0.04 ± 0.002 – 0.05 ± 0.008 mg L^{-1} respectively. Alam *et al.* (2002) studied the carp polyculture in pond and reported water temperature, transparency, pH and alkalinity as 31.85 °C, 30.11 cm, 6.98 mg L^{-1} and 125 mg L^{-1} respectively. Hossain *et al.* (2008) also reported similar water quality parameters in polyculture ponds: water temperature (25.6 – 25.8 °C), DO (5.3 – 5.6 mg L^{-1}), pH (7.7 – 7.9) and transparency (28.5 – 29.7 cm). Water temperature from 27.1 – 28.7 °C, DO from 5.2 – 5.9 mg L^{-1}, transparency from 18.2 – 25.5 cm and pH from 8 to 8.2 were also reported in polyculture pond (Ahmad *et al.* 2013). More or less similar water quality parameters were also reported by Mamun and Mahmud (2014). The mean values of water quality parameters in this study were found within the suitable range for fish culture (Alikunhi 1957; Swingle 1967; Boyd 1998).

3.2 | Fish growth

Significant variation ($P < 0.05$) among the treatments in terms of final weight, weight gain and SGR was found for NMCs (Table 3). Weight variation of the harvested fishes might be due to species type, availability of food according to choice and feeding frequency and the interactions among species (Habib *et al.* 2003). The mean final weight of *H. molitrix*, *C. carpio* and *C. idella* varied between 580 – 598 g, 540 – 567 g and 516 – 542.5 g respectively in a carp polyculture pond (Hossain *et al.* 2008). The mean weight gain of NMCs were 469.03 g (*L. rohita*), 347.9 g (*C. catla*) and 321.67 g (*C. mrigala*) in polyculture where the initial mean weight was 291.07, 230 and 198 g respectively (Mamun and Mahmud 2014). SGR of *H. molitrix*, *C. catla*, *L. rohita*, *C. mrigala*, *C. carpio* and *C. idella* was 1.14 ± 0.31, 1.14 ± 0.32, 0.95 ± 0.26, 1.05 ± 0.25, 1.09 ± 0.28 and 1.31 ± 0.3 respectively in carp polyculture pond (Asadujjaman and Hossain 2016). No significant variation among the treatments in survival rate was found. The survival rate rates of *L. rohita* (85.42%), *C. mrigala* (81%) and *C. catla* (80%) as reported by Mamun and Mahmud (2014) was more or less similar to the present study.

TABLE 2 Water quality parameters in different treatments

Parameters	*Treatments (Mean ± SE)*				*F*	*P value*
	T_1	*T_2*	*T_3*	*T_4*		
Water temperature (°C)	26.72±1.04	26.62±1.08	26.58±0.97	26.75±1.08	0.028	0.464
Water transparency (cm)	35.00±0.83	36.04±1.26	36.04±1.40	37.17±0.86	0.629	0.605
pH	7.38±0.10	7.40±0.11	7.57±0.10	7.45±0.11	3.018	0.044
Dissolved oxygen (mg L^{-1})	5.52±0.14	5.39±0.19	5.30±0.13	5.85±0.46	0.815	0.500
Free CO_2 (mg L^{-1})	4.92±0.17	5.26±0.10	5.58±0.12	5.56±0.05	6.576	0.003
Ammonia-Nitrogen (NH_3-N, mg L^{-1})	0.05±0.008	0.05±0.012	0.04±0.008	0.04±0.002	1.334	0.483
Alkalinity (mg L^{-1})	100.38±2.68	99.96±4.71	110.38±6.21	109.38±5.19	0.217	0.291

3.3 | Fish yield

Yield of all NMCs and *H. molitrix* varied significantly ($P < 0.05$) among the treatments. The total fish yield also varied significantly ($P < 0.05$) from 3743.3 ± 59.18 (in T_4) to 4011.2 ± 90.98 (in T_1) kg ha^{-1} 6-$month^{-1}$ (Table 4). The yearly yield of *H. molitrix*, *C. carpio* and *C. idella* was recorded as 1920, 1304 and 1164 kg ha^{-1} respectively with a stocking density of 10000 individuals ha^{-1} and species combination of 40% silver carp, 30% common carp and 30% grass carp (Hossain *et al.* 2008). The yearly fish production is found to be ranged as 3119 to 4067 kg ha^{-1} in the traditional carp polyculture system in Bangladesh (Hossain *et al.* 1997; Mazid *et al.* 1997).

TABLE 3 Growth of fishes under different treatments

Species	*Treatments & ANOVA results*	*Initial weight (g)*	*Final weight (g)*	*Weight gain (g)*	*SGR (%, bw d^{-1})*	*Survival rate (%)*
Labeo rohita	T_1	74.75±1.25[a]	577.50±8.54[a]	502.75±8.94[a]	1.14±0.01[a]	93.50±0.65[a]
	T_2	75.50±0.65[a]	558.00±8.98[ab]	482.50±8.76[ab]	1.11±0.01[a]	93.00±0.91[a]
	T_3	74.75±1.25[a]	547.75±11.45[bc]	473.00±11.07[bc]	1.11±0.01[ab]	90.00±2.12[a]
	T_4	75.75±1.80[a]	520.00±4.08[c]	444.25±3.64[c]	1.07±0.01[b]	93.00±1.47[a]
	F	0.16	7.62	8.09	5.24	1.30
	P	0.923	0.004	0.003	0.015	0.321
Catla catla	T_1	174.75±3.71[a]	1100.00±7.36[b]	925.25±11.05[b]	1.02±0.02[a]	92.50±0.29[a]
	T_2	173.00±6.10[a]	1105.00±18.48[b]	932.00±21.77[b]	1.03±0.03[a]	91.25±1.25[a]
	T_3	168.25±8.29[a]	1168.80±11.97[a]	1000.05±6.96[a]	1.08±0.02[a]	91.50±1.66[a]
	T_4	170.50±5.58[a]	1043.20±8.50[c]	872.75±13.47[c]	1.01±0.02[a]	93.00±1.47[a]
	F	0.22	17.23	13.32	2.06	0.42
	P	0.934	<0.001	<0.001	0.159	0.745
Cirrhinus mrigala	T_1	66.50±3.39[a]	522.50±2.50[b]	456.00±5.64[b]	1.15±0.03[a]	91.75±1.31[a]
	T_2	64.00±4.45[a]	563.50±7.12[a]	499.00±9.24[a]	1.21±0.04[a]	91.50±1.44[a]
	T_3	66.50±7.41[a]	535.75±7.05[b]	469.25±9.56[b]	1.17±0.06[a]	90.00±2.12[a]
	T_4	68.00±3.34[a]	500.00±7.07[c]	432.00±9.98[c]	1.11±0.03[a]	91.00±1.47[a]
	F	0.11	17.96	10.27	0.99	0.23
	P	0.951	<0.001	<0.001	0.431	0.875
Hypopthalmichthys molitrix	T_1	106.25±2.84[a]	964.50±22.74[a]	860.50±21.18[a]	1.05±0.01[a]	87.50±3.86[a]
	T_2	106.75±2.67[a]	953.00±13.05[a]	848.00±11.45[a]	1.05±0.01[a]	85.75±2.87[a]
	T_3	107.25±2.95[a]	952.25±29.14[a]	846.50±28.07[a]	1.05±0.02[a]	87.25±1.97[a]
	T_4	105.50±1.85[a]	947.00±30.52[a]	841.00±30.11[a]	1.02±0.03[a]	86.50±2.99[a]
	F	0.12	2.23	2.39	0.94	0.11
	P	0.969	0.402	0.391	0.500	0.975
Aristichthis nobilis	T_1	104.00±2.74[a]	859.25±33.91[a]	755.25±32.08[a]	1.03±0.02[a]	90.75±3.04[a]
	T_2	105.00±2.55[a]	849.75±49.73[a]	744.75±50.45[a]	0.94±0.05[a]	88.25±3.64[a]
	T_3	105.75±3.19[a]	856.00±59.26[a]	750.25±56.70[a]	0.96±0.04[a]	89.75±2.17[a]
	T_4	106.00±1.18[a]	840.00±26.24[a]	734.00±26.28[a]	0.94±0.06[a]	89.00±3.56[a]
	F	0.08	1.06	1.09	0.84	0.07
	P	0.948	0.137	0.120	0.451	0.950
Cyprinus carpio	T_1	58.25±3.57[a]	587.50±16.99[a]	529.25±19.35[a]	1.18±0.05[a]	81.25±2.50[a]
	T_2	62.25±7.28[a]	593.25±33.60[a]	531.00±31.30[a]	1.15±0.05[a]	75.75±5.01[a]
	T_3	65.75±6.76[a]	586.25±69.05[a]	520.50±69.52[a]	1.13±0.10[a]	77.75±3.47[a]
	T_4	61.50±9.39[a]	579.25±37.60[a]	517.75±43.13[a]	1.12±0.12[a]	73.00±2.87[a]
	F	0.19	0.31	0.26	0.07	0.93
	P	0.901	0.816	0.854	0.974	0.455
Ctenopharyngodon idella	T_1	103.00±2.48[a]	900.25±51.57[a]	797.25±49.86[a]	1.07±0.03[a]	88.75±3.20[a]
	T_2	104.25±2.84[a]	915.00±46.13[a]	811.50±48.59[a]	1.01±0.05[a]	86.75±3.07[a]
	T_3	104.75±1.44[a]	895.25±88.13[a]	790.50±88.79[a]	1.04±0.08[a]	88.75±1.70[a]
	T_4	102.75±0.95[a]	910.00±35.30[a]	807.75±35.61[a]	0.94±0.04[a]	89.25±1.65[a]
	F	0.22	1.60	1.56	1.27	0.20
	P	0.883	0.241	0.250	0.328	0.898

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

Yearly fish yield of 3400 – 6800 kg ha^{-1} has been observed from the earthen polyculture ponds of north-east Indian region (Shing *et al.* 2013). The yield of carp polyculture was found as 5361.5 – 11321.7 kg $ha^{-1}yr^{-1}$ (Hosen *et al.* 2014). Similar total yield (3675.33 kg ha^{-1} 6-$month^{-1}$) was also reported in carp polyculture pond (Asadujjaman and Hossain 2016).

TABLE 4 Fish yield in different treatments

Species	Fish production (kg ha^{-1} 6-$month^{-1}$)				F	P-value
	T_1	T_2	T_3	T_4		
Labeo rohita	929.12±21.88^{a}	886.51±15.14^{ab}	840.88±25.31^{bc}	816.10±7.57^{c}	7.12	0.005
Catla catla	753.98±5.99^{b}	746.80±9.22^{b}	792.27±13.67^{a}	719.04±14.75^{b}	7.80	0.006
Cirrhinus mrigala	620.14±13.45^{b}	677.17±14.08^{a}	625.45±13.73^{b}	583.03±20.71^{b}	6.02	0.010
Hypophthalmichthys molitrix	1157.51±53.54^{a}	1110.36±73.77^{a}	1126.25±85.08^{a}	1108.67±30.49^{a}	0.67	0.136
Aristichthys nobilis	325.13±19.52^{a}	315.43±6.95^{a}	323.11±10.68^{a}	314.02±10.55^{a}	0.81	0.512
Cyprinus carpio	212.53±12.91^{a}	198.29±12.47^{a}	200.66±29.49^{a}	187.27±19.61^{a}	0.49	0.695
Ctenopharyngodon idella	174.52±13.85^{a}	173.60±12.01^{a}	172.97±19.24^{a}	178.05±7.10^{a}	1.39	0.293
All species	4011.20±90.98^{a}	3951.71±99.50^{a}	3938.52±107.83^{a}	3743.30±59.18^{b}	4.63	0.014

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

3.4 | Economics of carp polyculture

The mean total cost varied from 349300 (in T_3) to 351310 (in T_2) BDT ha^{-1} 6-$month^{-1}$. The net half yearly return (BDT ha^{-1}) and CBR significantly ($P < 0.05$) varied from 434540 (T_4) to 497290 (T_1) and 1.24 (T_4) to 1.42 (T_1) respectively (Table 5). In a carp polyculture system, the total cost, net return and net benefit (all as BDT ha^{-1} 6-$month^{-1}$) and CBR varied from 123430.5 – 235930.5, 235068.4 – 418376.85, 111639.90 – 206744.85 and 0.77 – 1.67 respectively (Asadujjaman and Hossain 2016).

TABLE 5 Economics of carp polyculture in different treatments

Parameters	Treatments				F	P
	T_1	T_2	T_3	T_4		
Variable costs (BDT ha^{-1})						
Seed	93909.00±689.25^{a}	94500.00±320.83^{a}	93804.00±602.96^{a}	94246.00±675.89^{a}	0.29	0.831
Feed	96950.00±667.76^{a}	96418.00±391.39^{a}	96714.00±1104.5^{a}	96510.00±444.15^{a}	0.24	0.869
Lime	6655.20±199.21^{a}	7114.80±280.01^{a}	6917.00±202.79^{a}	7114.80±280.01^{a}	1.62	0.236
Fertilizer	5307.80±43.11^{a}	5253.20±27.63^{a}	5252.80±52.42^{a}	5253.00±27.79^{a}	0.49	0.697
Labour	35343.00±135.89^{a}	35331.00±98.91^{a}	35408.00±88.48^{a}	35339.00±97.07^{a}	0.11	0.952
Fixed costs (BDT ha^{-1})						
Pond lease value	112500.00±17.84^{a}	112690.00±40.21^{a}	112200.00±336.45^{a}	112330.00±379.1^{a}	0.69	0.576
Total cost (BDT ha^{-1})	350670.00±691.8^{a}	351310.00±299.7^{a}	350300.00±1059.9^{a}	350790.00±1350.6^{a}	0.84	0.499
Total return (BDT ha^{-1})	847960.00±8513.3^{a}	822530.00±4183^{b}	843730.00±10400^{ab}	785330.00±6149.7^{c}	13.88	<0.001
Net benefit (BDT ha^{-1})	497290.00±8290.8^{a}	471230.00±4341.9^{b}	493430.00±11299^{ab}	434540.00±6687.4^{c}	12.95	<0.001
Cost Benefit Ratio (CBR)	1.42±0.02^{a}	1.34±0.01^{a}	1.41±0.04^{a}	1.24±0.02^{b}	11.52	<0.001

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

Overall findings indicated that mean water quality parameters were found within the suitable range for fish farming in pond. Growth (in terms of mean final weight, weight gain and SGR) and yield of *L. rohita* was significantly higher with treatment T_1 (NMCs from the Padma) and that of *C. catla* and *C. mrigala* was significantly higher with treatment T_3 (NMCs from the Halda) and treatment T_2 (NMCs from the Jamuna) respectively. Net yield of *L. rohita* of treatment T_1 was 4.58% higher than treatment T_2, 9.49% than that of treatment T_3 and 12.61% than treatment T_4. Net yield of *C. catla* of treatment T_3 was 6.47%, 7.13% and 11.27% higher than treatment T_1, T_2 and T_4 respectively. Net yield of *C. mrigala* of treatment T_2 was 8.42%, 6.63% and 13.9% higher than treatment T_1, T_3 and T_4 respectively. Such variation in growth and yield with NMCs under different wild sources might be due to the natural phenomenon of the seed quality of these sources. However, for total fish yield and CBR, no significant difference was found among the treatments T_1, T_2 and T_3 and these three treatments (stocked with wild sourced NMCs) varied more significantly than treatment T_4 (stocked with hatchery produced seeds).

Findings clearly indicated that carp polyculture of wild seeds performed better in terms of growth, yield and economics over hatchery produced seeds. Thus, such variation between hatchery and wild seeds may be due to the quality degradation of the hatchery produced seeds. Almost similar assumption was made by Iram *et al.* (2013) who reported that the Chinese carps had an innate affinity towards rapid growth whereas the native major carps lost the vitality to grow fast due to continuous propagation. Present findings also agreed with Shah (2010) who found comparatively slower growth rates of hatchery produced carps than that of wild sources and also with Biswas *et al.* (2008) who reported best performances of wild sourced carp seeds (seeds from Halda River) over hatchery produced carp seeds in polyculture study.

4 | CONCLUSION

Carp polyculture of wild sourced NMCs were more profitable than that of hatchery produced seeds. Growth and yield performances of NMCs like *L. rohita*, *C. catla* and *C. mrigala* were found better with Padma, Halda and Jamuna Rivers respectively. Further research is recommended to find out the profitable stocking combination of these better performed wild sourced NMCs with hatchery produced non-native carps in pond polyculture system.

ACKNOWLEDGEMENTS

Authors are thankful to Indrozit hatchery, Faridpur for assistance in conducting the research through logistic and financial supports from their brood development program under Aquaculture for Income and Nutrition Project (AIN) of WorldFish (Memo # Indrozit hat/Fpr/06/107/13).

REFERENCES

Ahmad M, Abbas S, Javid A, Ashraf M, Iqbal KJ, Azmat H, Khan T, Mahmood S and Haider R (2013) Effect of varying stocking density of bottom feeder fish *Cirrhinus mrigala* and *Cyprinus carpio* on growth performance and fish yield in polyculture system. International Journal of Biological Research 5(11): 278–285.

Asadujjaman M and Hossain MA (2016) Fish growth, yield and economics of conventional feed and weed based polyculture in ponds. Journal of Fisheries 4(1): 353–360.

Alam MJ, Kohinoor AHM, Islam MS and Mazid MA (2002) Polyculture of carps using over-wintered fingerlings under different stocking densities. Bangladesh Journal of Fisheries Research 6(2): 117–124.

Alikhuni KH (1957) Fish culture in India. F.M. Bulletin of Indian Countries Agriculture Research 20: 144.

Azim ME and Wahab MA (2003) Development of a duckweed-fed carp polyculture system in Bangladesh. Aquaculture 18: 425–438.

Barman BK, Kunda M and Wahab MA (2012) Technologies for improving quality carp seed production in Bangladesh. In: Book of abstracts, fifth fisheries conference and research fair 2012, Bangladesh Fisheries Research Forum (BFRF), 18–19 January 2012, Dhaka, Bangladesh, p. 182.

Biswas BK, Shah S, Takil K and Kumali H (2008) A comparison of growth performance of Indian major carps, *Catla catla* (Hamilton) and *Cirrhinus cirrhosus* (Bloch) from natural and hatchery sources in Bangladesh. Aquaculture Science 56(2): 245–251. doi: 10.11233/ aquaculturesci.56.245

Boyd CE (1998) Water quality for fish pond. Aquaculture Research and Development Series No. 43. Auburn University, Alabama, USA, p. 37.

Brett JR and Groves TDD (1979) Physiological energetics. In: Hoar WS, Randall DJ and Breet JR (eds) Fish Physiology, vol. VIII, Bioenergetics and Growth. New York, NY: Academic Press, 280–352 pp.

Chughtai MI, Mahmood K and Awan AR (2015) Growth performance of carp species fed on salt-tolerant roughages and formulated feed in brackish water under polyculture system. Pakistan Journal of Zoology 47(3): 775–781.

DoF (2017) National Fish Week 2017 Compendium. Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh, p. 160 (in Bengali).

DoF (2014) National Fish Week 2014 Compendium. Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh, p. 144 (in Bengali).

DoF (2012) National Fish Week 2012 Compendium. Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh, p. 144 (in Bengali).

Gomez KA and Gomez AA (1984) Statistical procedure for agricultural research. 2nd Edition, John Wiley & Sons, p. 697.

Habib MAB, Sarker B, Hossain MS and Sarder MRI (2003) Species interaction between carp species in polyculture system. Bangladesh Journal Fisheries Research 7(1): 27––32.

Hosen MA, Shahjahan M, Rahman MS. and Alam MJ (2014) Effects of artificial feed on growth and production of fishes in polyculture. International Journal of Agricultural Research, Innovation & Technology 4(2): 11–15.

Hossain KZ, Miah MJU and Ali MH (2008) Effects of inorganic fertilizers on the growth and production performance of exotic carps in polyculture system. Progressive Agriculture 19(2): 129–137.

Hossain MA and Bhuiyan AS (2007) Growth performance of carp in ponds in red soil zone of northern Bangladesh. Journal of Science Foundation 5(1): 59–64.

Iram I, Ahmed N, Amir I, Hussain T, Saif F and Naz S (2013) Growth performance of indigenous and exotic fish species after yearling stage in polyculture system. Middle-East Journal of Scientific Research 16(2): 256–263.

Karim M and Rahman MM (2013) Farmers training manual of carp polyculture. Aquaculture for Income and Nutrition project (AIN), WorldFish, Bangladesh and South Asia Office, Banani, Dhaka, Bangladesh, p. 180.

Mamun AA and Mahmud AI (2014) Study on growth performance and production of juvenile Indian major carp (*Catla catla*, *Labeo rohita* and *Cirrhinus cirrhosus*) and their hybrids. Journal of Fisheries and Aquatic Science 9(3): 92–108.

Mazid MA, Zaher M, Begum NN, Ali MZ and Nahar F (1997) Formulation of cost effective feeds from locally available ingredients for carp polyculture system for increased production. Aquaculture 151: 71–78.

Singh UP, Pandey NN and Bisht HCS (2013) Growth performance of exotic carps in poultry waste recycled ponds. International Journal of Advanced Research 1(7): 239–248.

Shah MS (2010) Genetics of aquaculture and fisheries management. Fisheries and marine resource technology discipline, Khulna University, Khulna, Bangladesh, p. 267.

Swingle HS (1967) Standardization of chemical analysis for water and pond muds, FAO, Fish Rep 494: 397–421.

Talukdar MZ, Shahjahan H and Rahman MS (2012) Suitability of duckweed (*Lemna minor*) as feed for fish in polyculture system. International Journal of Agriculture, Innovation & Technology 2(1): 42–46.

CONTRIBUTION OF THE AUTHORS

MRIK Research design, primary data collection and validation, statistical analysis and draft manuscript (MS) writing; **MTP** assist in statistical analysis and drafting MS preparation; **MGST** Review primary data and data analysis, review and comments on draft MS; **MAH** review and validation of data and statistical analysis; review and finalization of the MS.