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Study on the Growth Performance and Production of Juvenile Indian Major Carps (*Catla catla*, *Labeo rohita* and *Cirrhinus cirrhosus*) and Their Hybrids

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ABSTRACT

Three different experiments were conducted to study the growth performance and production of juvenile Indian major carps and their hybrids, (catla-*Catla catla*; rohu-*Labeo rohita* and mrigal-*Cirrhinus cirrhosus*) from January 2008 to October 2008 in Field Laboratory Complex of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. Pure fish species of Indian major carps, hybrids and both pure species (65%) and hybrids (35%) were stocked in experiment I, II and III, respectively with three replicates. Forty fish per decimal were stocked in each of nine ponds with pond area of 2 dec. The ratio of pure species of catla, rohu and mrigal was 40:30:30 in experiment I whereas the hybrids of catla×rohu, catla×mrigal and mrigal×rohu were stocked at the same ratio in the experiment II. On the other hand, in experiment III pure catla, rohu and mrigal were stocked at the ratio 40:30:30 and hybrids were stocked at the same ratio. All the experimental ponds were subjected to the same regime of feeding and fertilization. The physico-chemical parameters such as temperature, pH, alkalinity, dissolved oxygen, transparency, nitrate-nitrogen, phosphate-phosphorus, soil quality and abundance of plankton were found to be in the expected range. During observing the growth performances in experiment I, catla showed highest average weight gain (177.97±1.54 g) that was significantly ($p<0.01$) different from the values of mrigal (123.67±5.77 g) and rohu (177.94±1.73 g). Experiment II showed highest average weight gain in catla×rohu hybrids 209.2±1.15 g. Experiment III showed the highest average weight gain in pure mrigal 208.43±1.15 g followed by the pure catla 148.5±1.15 g and hybrids of catla×rohu 132.53±1.5 g. Catla×mrigal and mrigal×rohu showed the lower performances in average weight gain both in experiment II and experiment III. The highest net production was found 961.91±118.64 kg ha^{-1} 10 months in experiment II followed by the net productions of pure and hybrids of juvenile Indian major carps 951.42±39.70 kg ha^{-1} 10 months in experiment III and the same pure species 810.98±24.85 kg ha^{-1} 10 months in experiment I.

Key words: Growth, production, indian major carps, hybrids

INTRODUCTION

In Bangladesh total fish production is around 2.10 million metric tons and 44% of the production comes from open waters including rivers and 56% from closed water bodies (DoF, 2005).

For the production in closed water bodies, more than 50% production comes from cultures of Indian major carps and the three species *L. rohita*, *C. catla* and *C. cirrhosus* cover 90% of the major carps. The above three species are also found in rivers and other big water bodies. Therefore, in total major carps contribute around 30% of the total fish production. The Indian major carp species are known to be able to hybridize and hybrids are fertile and can be backcrossed to the parental species (Das *et al*., 1980; Padhi and Mandal, 1997). Furthermore, hybridization has been shown to have a significant impact on production related traits (notably growth), with some studies reporting a growth rate of F_1 hybrids intermediate between that of the parent species. Chaudhuri (1971), Natarajan and Mishra (1976) and Das *et al*. (1980) and other studies reporting growth rates lower than either of the parental species (Ibrahim, 1977). Altogether, six interspecific and 13 intergeneric hybrids were produced among the four species of Indian major carps belonging to three genera, i.e., *Catla, Labeo* and *Cirrhinus*. Over three decades of research on hybridization showed that these major carps with distinct morphological characters are highly compatible and able to produce viable and fertile hybrid progenies. Mature interspecific and intergeneric hybrids could be induced to produce F_2 progeny or backcross and triple cross hybrids. It is necessary to prevent indiscriminate hybridization. These carps are highly compatible to interbreed. Also, since almost all interspecific and intergeneric hybrids were found fertile, one should be more cautious of their crossbreeding as this may cause serious damage to the original gene pool through genetic introgression (Padhi and Mandal, 1994). Recent studies showed that high incidence of hybridization have been taking place in the hatcheries of Bangladesh (Simonsen *et al*., 2004, 2005). Hybridization may result in two outcomes, either hybrid vigor or hybrid depression. Both features are recognized in agriculture, hybrid vigor mainly from plant production where F_1 seeds will lead to increased yield (Suzuki *et al*., 1981). Hybrid depression is often seen when crossing takes place between closely related species, e.g,. horse and donkey. The growth performance may also depend on the environment as found for the two abalone species, *Haliotis kamtschatkana* and *H. discus* hannai. The growth of the hybrid was superior to both parental species at 18°C but lesser than *H. kamtschatkana* at 8°C (Hoshikawa *et al*., 1998). Likewise, hybrid production has been reported in the Indian major carps. Chaudhuri (1971) and Das *et al*. (1980) reported that the catla×rohu hybrids of Indian major carp grew faster than rohu but not as quick as catla. Better growth rate of hybrid than the pure species was also found when they were cultured separately (Alikunhi *et al*., 1971). Since hybridization is becoming a common phenomenon in carp hatcheries it is important to study the characteristics of hybrids and their impact on total fish production. In view of the above the present study was conducted to achieve the following objectives:

- To observe the growth variations between pure and hybrids of juvenile Indian major carps
- To assess the impact of hybridization on production of juvenile Indian major carps
- To identify the morphological and meristic differences of hybrids from the pure species of juvenile Indian major

MATERIALS AND METHODS

Brood collections and rearing: Mature brood fish of Indian major carps were collected from different sources in Mymensingh district and were reared in the ponds located at Mashkanda Fish Seed Multiplication Farm in Mymensingh district for the purpose of producing desired fries before October 2008. The broods were reared in the farm with good care and maintained the genetic quality. The weight of individual catla, rohu and mrigal obtained ranging from 3-3.5, 1.5-2 and 1-1.5 kg, respectively.

Fry production: Fries of pure fish species of catla, rohu, mrigal and their hybrids were produced by hypophysation in Mashkanda Fish Seed Multiplication Farm, Mymensingh. Fertilization of eggs with sperm through cross breeding as follows produced different hybrids:

Female catla with male rohu ($C_{♀} \times R_{♂}$)
Female catla with male mrigal ($C_{♀} \times M_{♂}$)
Female mrigal with male rohu ($M_{♀} \times R_{♂}$)

When the fry reached to fingerling size in about 80 days rearing they were stocked for growth experiment.

Experimental pond preparation: The experimental ponds were prepared by using rotenone at the dose of 20 mg L^{-1} water for eradicating unwanted fish species. Lime was used at the rate of 1 kg dec^{-1} to improve pH of soil and water and also the pond productivity. Fertilizers were applied to increase the plankton density in pond waters. Doses of fertilizers were cowdung 5 kg dec^{-1}., urea 100 g dec^{-1}. and Triple Supper Phosphate (TSP) 100 g dec^{-1}. Seven day after fertilization, the pond water became greenish colored with the abundance of phytoplankton and zooplankton and ready for fry stocking.

Experimental design: Nine ponds were selected to conduct the present study under three experiments namely experiment I, experiment II and experiment III, each with three replications. All the experimental ponds were rectangular in size with 2 decimal of water area. The ponds were connected with water supply line to provide water from deep tube-well whenever necessary.

Brood collections and rearing: They were provided with supplementary feed consisting of rice bran, mustard oil cake and fishmeal at the ratio of 45:45:10 for 3 months before conducting the experiment. Vitamin-E was supplemented with feed to enhance the gonadal development of fish. The feed was administered twice daily at the rate of 4-5% of the body weight. Organic and inorganic fertilizers were applied at the rate of 5 kg/deci/15 days and 150 g/deci/15 days, respectively to increase the natural food production of the pond.

Fry production: A single dose injection was given to the each male whereas two injections with PG extract were used for the each female. PG were used as 1.0 to 2.0 mg kg^{-1}, 1.0-1.5 mg kg^{-1} b.wt. and 1.0 to 1.5 mg kg^{-1} for the 1st dose followed by the 2nd dose of 5.0 to 6.0, 4 to 5 and 5 to 6.0 mg kg^{-1} for the females of catla rohu and mrigal, respectively. A six hour time interval was maintained between 1st and 2nd dose of injection. Males of all three species were induced with PG extract at a dose of 2.0 mg PG kg^{-1} at the time of 2nd injection of the females. During administration of injection, fish were wrapped by a soft and wet cloth and kept lying on soaked foam. The PG solution was injected intramuscularly on the dorsal side behind the pectoral fin. The needle was inserted at about 45° angle to the body surface of fish. The spawners were handled very carefully during the whole operation. After 6 hours of the 2nd injection of female fish eggs of each species were collected separately by stripping method and fertilized with the sperm of corresponding male and produced pure fish fry separately. Fertilized eggs were washed with saline water and transferred to hatching jars separately for hatching. The newly hatched larvae were kept in incubators for about 3 days for yolksac full absorption. The larvae were then carried in polythyne bags with oxygen and stocked in nursery ponds.

Table 1: Stocking of fry at each experimental pond

	No. of fry and experiment		
Fish fry	I	II	III
Catla	32	-	20
Rohu	24	-	16
Mrigal	24	-	16
C×R	-	27	10
C×M	-	27	10
M×R	-	26	8
Total	80	80	80

C×R: Catla×Rohu, C×M: Catla×Mrigal and M×R: Mrigal×Rohu, No.: Number

Experiment I: Experiment I was designed to study the growth performance of pure fish species as catla, rohu and mrigal produced in FSMF, with the stocking ratio of 40:30:30, respectively. The stocking density was 40 fish deci^{-1} for all the replicated ponds and the total number of fish stocked in each replication was 80 (Table 1).

Experiment II: In this experiment only the hybrids of catla × rohu, catla × mrigal and mrigal × rohu were stocked to study their growth performances. As having no knowledge on feeding habit of hybrids, they were stocked in equal number (Table 1). As to maintain the stocking number (80 fish pond^{-1}), a little variation in mrigal × rohu in number was considered.

Experiment III: In this experiment, pure species of Indian major carps produced in FSMF together with hybrids were stocked to study their comparative growth performances. Thirty five percent Indian major carps were replaced by the hybrids. Stocking ratio of catla: Rohu: Mrigal was 40:30:30 and the hybrids were stocked at an equal proportion (Table 1).

Plankton study: In each case an integrated 10 L of water sample were collected and passed through plankton nets of 10, 30 and 55 μm mesh size. Each sample was then made to 50 mL by adding of water and preserved in 10% buffered formalin. For analysis, a sub-sample of 1 mL was drawn with a wide-mouthed pipette and poured into a Sedgwick Rafter counting chamber of one ml capacity and organisms were counted as outlined by Boyd and Lichtkoppler (1979):

$$N=\frac{A\times 1000\times C}{V\times F\times L}$$

Where:
N: No. of plankton cells per litre
A: Total No. of plankton counted
C: Volume of final concentrate of samples in ml
V: Volume of a field in cubic mm in the counting chamber
F: No. of the field counted
L: Volume of original water in litre

Other management techniques: Liming, fertilizing, pulling horra and agitation of water were furnished when it was needed according to the existing situations of the experimental ponds. Cow

dung, urea and TSP were applied at the rate of 2 kg, 50 g and 50 g dec^{-1} respectively when secchi disc reading became over 35 cm. TSP was always soaked in water for overnight and then mixed with urea, cowdung and were spread to the pond waters. In case of excessive planktonic growth or bloom that might cause water quality deterioration, water exchange was done to maintain the quality parameters within suitable level. To discharge the toxic gases from the pond bottom, if any, horra was pulled in the bottom. There were a large number of snails in the experimental ponds which were tried to remove manually and also biologically by stocking black carp (*Mylopharyngodon piceus*). The embankments of the ponds were tried to keep clean all the time. The pond waters colors were observed daily during the whole experimental periods.

Growth performance: Monthly record of length and weight of individual fish was kept at each sampling date from January 2008 to October 2008. Average growth in terms of weight increment of fish in each replication of the three experiments was calculated as follows:

Average weight gain (g) = Average final weight (g)-Average initial weight (g)
Average growth in length = Average length of individual fish in 3 replicates
Average growth in weight = Average weight of individual fish in 3 replicates

Specific growth rate (%SGR): Specific growth rate (%SGR) is the instantaneous change of body of fish as the percent increase in body weight per day over a certain interval which is measured as outlined by Brown (1957) as the following equation:

$$\text{SGR day}\,(\%) = \frac{\text{Log e}W_2 - \text{Log e}W_1}{T_2 - T_1} \times 100$$

Where:
W_1: Initial body weight (g) at time T_1 (day)
W_2: Final body weight (g) at time T_2 (day)

Average weight gain: Average weight gain and weight gain per day of fishes were calculated as follows:

Average wt. gain (g) = Average final weight (g)-Average initial weight (g)
Average weight gain (g)/day at different months:

$$\text{Weight gain per day} = \frac{\text{Weight (g) in present month} - \text{Weight (g) in previous month}}{\text{Days of month}}$$

Survival rate and production: To determine the survival rate and production of fishes, total fishes were caught by first seine netting and then by dewatering the ponds. Then, total number of fishes was counted species-wise and calculated the survivability and production of fishes as follows:

$$\text{Survival rate} = \frac{\text{No. of total obtained}}{\text{No. of total fish stocked}} \times 100$$

Table 2: Proximate composition of the feed ingredients and prepared feed

Feed ingredients	Moisture (%)	Dry matter (%)	Crude protein (%)	Lipid (%)	Ash (%)	Crude fiber (%)	Nitrogen free extract (NFE) (%)
Mustard oil cake	10.92	89.08	38.62	25.22	9.79	4.04	22.33
Wheat bran	12.94	87.06	19.00	7.60	4.27	5.28	63.85
Rice bran	10.74	89.26	15.54	7.55	13.15	6.05	57.71
Fish meal	13.16	86.84	29.52	21.19	33.51	9.62	6.06
Prepared feed	61.32	38.68	27.66	21.48	10.88	6.20	33.78

Nitrogen free extract was calculated as: 100−Protein (%)+Crude lipid (%)+Ash (%)+Crude fiber(%)

$$\text{Individual production (kg ha}^{-1}\text{/10 months)} = \frac{\text{Average weight gain (g)} \times \text{No. of fish obtained}}{2 \times 3 \times 1000} \times 247$$

[3 replicated ponds with 2 decimal each; 1 Hectare = 247 decimal]

Post stocking management: During the experimental period, ponds were observed regularly and monitored as follows.

Feeding: The stocked fish were fed with the prepared feed containing locally available feed ingredients viz., mustard oil-cake, rice bran, wheat bran and fishmeal. The proximate compositions of the feed ingredients were analyzed following the procedure of AOAC (1984) in the Nutrition Laboratory of Aquaculture Department, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh (Table 2). The protein content of the feed was approximately 25%. The stocked fish were fed with the prepared feed twice a day at the rate of 5% body weight and approximately two thirds of the total feed was provided at morning (0900-1000 h) and the rest of the ration at the afternoon (1600-1700 h).

Water quality monitoring: Various water quality parameters such as temperature (°C), transparency (cm), dissolved oxygen (mg L^{-1}), pH, total alkalinity (mg L^{-1}), phosphate-phosphorus (mg L^{-1}) and nitrate-nitrogen (mg L^{-1}) were recorded monthly throughout the experimental period. Water samples were collected from respective ponds between 900-1000 h. on each sampling date (14th day of each month). Most of the water quality parameters were measured on the spot except phosphate-phosphorus (mg L^{-1} and nitrate-nitrogen (mg L^{-1}) which were analyzed in the Water Quality and Pond Dynamics Laboratory of the Faculty of Fisheries and in the central laboratory of Bangladesh Agricultural University, Mymensingh. The water quality parameters measured are presented in Appendix I.

Soil analysis: To determine the soil-water interaction, bottom soil samples were collected once a month from one representative pond of each experiment by Ekman Dredge (covering an area of 225 m^2) from the area of soil-water interface. About 0.5 kg soil from each pond placed into a separate labelled bag was carried to the laboratory. The samples were then air-dried, ground and sieved by 0.03 mm mesh sized sieve and kept in plastic bags marked with collection date and pond number for future analysis. The following chemical characteristics of the soil samples were determined in the laboratory: pH, phosphate, potassium, sodium, organic carbon and total nitrogen. The analysed results are presented in Appendix II.

Appendix I: Monthly variation in the water quality parameters in different experiments, average for three replicates

Water quality parameters	Expt. No.	Jan. 08	Feb. 08	Mar. 08	Apr. 08	May. 08	Jun. 08	Jul. 08	Aug. 08	Sep. 08	Oct. 08
Temp. (°C)	I	19.0	23.0	28.4	28.7	24.7	31.2	31.7	32.0	29.5	32.8
	II	19.0	22.9	28.9	29.3	24.0	29.7	30.9	30.9	29.5	32.6
	III	19.0	22.9	28.7	28.7	24.4	29.5	31.5	30.8	29.5	32.5
pH	I	7.1	7.8	8.2	8.2	7.6	7.5	7.5	7.7	7.6	6.8
	II	7.2	7.8	8.3	8.3	7.6	7.6	7.7	8.0	7.4	6.8
	III	7.1	7.9	8.1	8.3	7.0	7.6	7.7	7.6	7.5	6.6
D.O (ppm)	I	3.3	1.2	3.9	3.9	4.3	2.8	3.5	3.9	4.3	4.1
	II	3.0	1.3	4.8	4.3	4.4	2.6	3.4	3.6	4.0	3.9
	III	3.2	1.1	4.5	4.9	4.5	2.7	3.5	4.3	4.6	4.1
Alkalinity	I	92	167	173	147	140	127	113	113	113	107
(ppm)	II	100	160	167	147	133	133	127	120	100	127
	III	80	147	160	153	133	153	113	113	127	113
Transparency	I	22.0	25.7	20.7	15.9	17.7	27.3	23.7	24.3	19.3	26.3
(cm)	II	24.0	25.3	20.3	23.5	18.9	28.7	27.3	24.3	19.0	25.3
	III	24.3	28.7	22.0	24.6	22.1	27.7	32.7	23.7	21.3	20.3
NO_3-N (mg L^{-1}	I	0.016	0.010	0.083	0.010	0.010	0.013	0.013	0.013	0.017	0.013
	II	0.020	0.013	0.060	0.010	0.010	0.010	0.023	0.013	0.006	0.013
	III	0.020	0.010	0.037	0.010	0.030	0.017	0.037	0.010	0.010	0.013
PO_4-P (mg L^{-1})	I	0.30	0.25	0.39	0.29	0.31	0.32	0.29	0.36	0.33	0.31
	II	0.15	0.13	0.38	0.14	0.34	0.33	0.35	0.34	0.18	0.34
	III	0.13	0.12	0.47	0.23	0.18	0.20	0.23	0.40	0.25	0.22

Appendix II: Monthly variation in the soil quality parameters in different experiments

Soil quality parameters	Expt. No.	Jan. 08	Feb. 08	Mar. 08	Apr. 08	May. 08	Jun. 08	Jul. 08	Aug. 08	Sep. 08	Oct. 08
pH	I	5.8	6.4	5.9	6.2	5.8	6.2	6.2	6.2	5.8	6.3
	II`	6.0	5.9	5.5	6.4	6.0	5.5	6.4	6.0	6.0	5.8
	III	5.6	5.6	5.8	6.0	5.9	5.8	6.0	6.4	5.5	5.9
Nitrogen (%)	I	0.28	0.28	0.27	0.25	0.31	0.25	0.25	0.22	0.21	0.26
	II	0.22	0.27	0.27	0.31	0.28	0.32	0.20	0.20	0.25	0.22
	III	0.25	0.20	0.28	0.29	0.22	0.22	0.28	0.25	0.21	0.27
Organic carbon	I	1.27	1.23	1.35	1.21	0.86	1.21	1.39	1.09	1.09	1.08
(%)	II	1.01	1.04	1.00	1.31	0.88	0.90	0.59	0.71	1.11	1.16
	III	1.01	1.02	1.16	1.56	1.07	0.80	0.73	0.61	0.98	0.98
Phosphorous	I	22	20	20	20	20	20	11	14	16	15
(mg L^{-1})	II	18	12	18	22	16	18	22	18	14	13
	III	16	16	16	24	18	18	18	16	12	14
Potassium	I	265	215	216	211	215	210	226	235	265	298
(mg L^{-1})	II	246	200	223	198	190	221	236	210	266	290
	III	240	235	225	210	210	225	218	235	280	285
Sodium	I	160	120	130	146	148	135	135	120	185	180
(mg L^{-1})	II	150	135	146	126	135	140	146	135	186	185
	III	140	146	148	120	146	135	148	130	190	180

Plankton study: For the qualitative and quantitative study of phytoplankton and zooplankton, water samples were collected from all the experimental ponds once a month before fish sampling. The mean number of plankton was recorded and expressed numerically per millilitre of water (cells mL^{-1}). The analysed plankton data are presented in Appendix III.

Appendix III: Abundance of Plankton Cell mL^{-1} of water in three different experiments during experimental period

Exp. No.	Pond	Jan. 08	Feb. 08	Mar. 08	Apr. 08	May. 08	Jun. 08	Jul. 08	Aug. 08	Sep. 08	Oct. 08
	14	48.5	142	106	111.5	66.5	99.5	97	129.5	60	68
I	16	100.5	116	90	143.5	87.5	90	124	89	77	79
	18	76.0	151	104	103.5	82	89	52.5	61	66.7	67
	13	96.5	111	118.5	119.0	109	117.5	94	71	111.5	60
II	15	170.5	260	182	162.0	124	128	223.5	56	60.5	65.5
	20	67.5	75	100.5	139.0	128	117	90	64.5	66.5	55
	17	67.5	139.5	99.5	63.5	71	107	117	46	61.5	59.5
III	19	80.5	167.5	156.5	154.5	86	116.5	74.5	56	60	62.5
	21	116.0	78	121	90.5	99	113.5	78.5	68	66.5	59

Fish sampling: Fish sampling was done at an interval of 30 days (every 15th day of each month) to adjust the feeding rate by measuring the weight of fish, to observe the health condition and to keep the record of length and weight of fish. Fishes were caught by seine net and about 30% of each species were sampled. Length of fishes was measured to the nearest cm with a centimetre scale fitted to a wooden measuring board. Weight to the nearest gram (g) was recorded by an electric balance (Model No. PB 5001-S, USA). During sampling tranquiliser was used to anaesthetize the fish for comfortable measurement. After recording the length and weight of fishes they again released to the respective ponds.

Growth study: For comparative growth study of fishes of the experiments, the following growth parameters were calculated and analyzed:

- Growth performance
- Specific growth rate (%SGR)
- Average weight gain
- Survival rate and production

Identification of catla, rohu, mrigal and their hybrids: For the identification of pure species and hybrids of Indian major carps at a glance some differences among them were mentioned. Shape and size of mouth, lips, body depth, pattern of scale, lateral line and some meristic and morphometric characters were considered as prominent differences for identification.

Statistical analysis: Data obtained from the present study was analyzed statistically to observe weather the growth performances of pure species of Indian major carps and their hybrids were significantly different or not in different experiments. The design of the experiment was set in such a way that analysis of variance could be done in completely randomized design (CRD). Duncan's New Multiple Range Test (DMRT) was done among the mean values of growth rate, weight gain, weight gain/day, specific growth rate (%SGR day), species-wise production and total production of each experiment.

RESULTS

The growth performance and production of juvenile Indian major carps (*C. catla*, *L. rohita* and *C. cirrhosus*) and their hybrids, the water parameters and other factors as obtained in the present study are presented below.

Water quality parameters: The physico-chemical parameters like water temperature, transparency, dissolved oxygen, pH alkalinity and nitrate-nitrogen recorded monthly during the experimental period is presented Appendix I. The lowest water temperature (19°C) was recorded in January in experiments I, II and III and the highest (32.8°C) was recorded in experiment I in October 2008. pH ranged from 7.1-8.2, 6.8-8.3 and 6.6 -8.3 were recorded from experiments I, II and III, respectively. The lowest pH (6.6) was found in experiment III during October 2008 and the highest pH (8.3) was found in experiment II during March 2008 and April 2008 and also same value was found in experiment III during April 2008. The lowest value of dissolved oxygen (1.1 ppm) was found in experiment I during February 2008 and the highest value (4.9) was found in experiment III during April 2008. The average value of DO ranged from 1.2-4.3, 1.3-4.8 and 1.1-4.9 were found in experiments I, II and III, respectively at morning during the entire study period. The total alkalinity measured were 92-173, 100-167 and 80-160 mg L^{-1} in experiments I, II and III where average values were 102.3, 131.4 and 129.2 mg L^{-1}, respectively. The water transparency in experiments I, II and III were between 15.9-26.3, 18.9-28.7 and 20.3-32.7 cm, respectively. The highest value of transparency (32.7 cm) was found in experiment III during July 2008 where the lowest value (15.9 cm) was found in experiment I during April 2008. Among the three experiments the transparency level in experiment III was almost higher followed by experiment II and I throughout the experimental period. Nitrate-nitrogen ranged from 0.010-0.083, 0.010-0.060 and 0.006-0.037 mg L^{-1} was found in experiments I, II and III during experimental period. Higher value of nitrate-nitrogen was recorded in experiment I. The phosphate-phosphorus content varied from 0.25-0.36, 0.13-0.35 and 0.12-0.47 mg L^{-1} in experiments I, II and III, respectively. It was found that experiment III had the highest (0.47 mg L^{-1}) and the lowest (0.12 mg L^{-1}) value of phosphate-phosphorus during March and February 2008, respectively. The soil quality parameters (pH, %organic carbon, %Nitrogen etc.) of the ponds were also found in suitable range Appendix II.

Plankton monitoring: The monthly investigation of plankton (both phytoplankton and zooplankton) revealed that a number of beneficial planktons were available in all the ponds but the abundance fluctuated within and between experiments at different months (Appendix III), or expressed in another way sufficient phytoplankton was present in each pond over the period. Comparatively less zooplankton both in kinds and number was available in most of the ponds. Some toxic plankton, such as *Microcystis* and *Anabaena* were identified in most of the pond samples, however, no definite effects of the planktons on fish growth were observed.

Growth, production and survival rate of pure strain in experiment I: The average growth of fishes in weight (g) at different months is shown in Appendix IV. The initial average weight (g) of catla, rohu and mrigal was 291.07±0.58 g, 230±2.89 g and 198±1.15 g while the final average weight (g) was 469.03±5.77g, 347.9±1.73 g and 321.67±1.15 g, respectively. During the beginning of experiment i.e., at the early January 2008, the initial weight of catla was significantly ($p<0.01$) higher than rohu and mrigal, respectively. The monthly average growth of catla was always higher than those of rohu and mrigal during the entire experimental period. The monthly average growth of rohu and mrigal was observed very close to each other and not significantly ($p<0.01$) different during the last few months of the experiment (Appendix IV).

Average weight gain (g day^{-1}) of catla, rohu and mrigal at different months in experiment I is shown in Appendix V. The highest weight gain day^{-1} of catla, rohu and mrigal was observed to be

Appendix IV: Monthly average growth in weight (g) as recorded from different experiments

Exp. No.	Fish	Initial	Jan. 08	Feb. 08	Mar. 08	Apr. 08	May. 08	Jun. 08	Jul. 08	Aug. 08	Sep. 08	Oct. 08
I	Catla	291.1	293	298.1	307	314.5	318.8	336.9	364.1	400.6	445.2	469
	Mrigal	198	200.6	202.6	210.5	218.3	225.7	252.7	261.3	289.7	306.1	321.7
	Rohu	230	231.3	234.3	240.9	252.9	264.3	284.9	307.8	316.6	331.2	347.9
II	C×M	177.87	178.87	181.03	184.6	192.33	197.53	207.67	221.87	253.07	273.47	288.07
	C×R	395.13	399.33	407.97	424.13	435.43	443.73	474.37	514.3	554.57	585.67	604.33
	M×R	200.53	202.67	205.27	215.87	227.3	237.77	251.67	262.13	273.6	284.5	306.27
III	Catla	440.2	441.53	444.4	447.77	453.9	461.07	476.07	491.47	531.63	564.93	588.77
	Mrigal	255.6	257.17	262.57	270.77	289.03	302.4	323.47	364.1	392.83	428.7	464
	Rohu	321.2	323.27	324.83	331.27	338.13	347.33	367.33	379.73	384.97	406.1	422.67
	C×M	180.9	184.53	190.13	194.63	199.57	205.63	215.4	238.43	250.47	262.83	278.13
	C×R	340.1	342.8	346.83	356.57	363.67	371.7	382.67	399.83	428.2	456.36	472.6
	M×R	201.6	202.23	206.13	213.13	218.43	224.03	234.5	252.4	281.63	296.9	330.03

Appendix V: Weight gain (g day^{-1}) of fishes at different months during the experimental period

Experiment No.	Fish	Jan. 08	Feb. 08	Mar. 08	Apr. 08	May. 08	Jun. 08	Jul. 08	Aug. 08	Sep. 08	Oct. 08
I	Catla	0.06	0.18	0.29	0.25	0.14	0.60	0.88	1.18	1.49	0.79
	Rohu	0.04	0.11	0.21	0.40	0.37	0.69	0.74	0.28	0.49	0.54
	Mrigal	0.04	0.11	0.21	0.40	0.37	0.69	0.74	0.28	0.49	0.54
II	C×R	0.14	0.31	0.52	0.38	0.27	1.02	1.28	1.30	1.04	0.60
	C×M	0.03	0.08	0.12	0.26	0.17	0.34	0.46	1.01	0.68	0.47
	R×M	0.07	0.09	0.34	0.38	0.34	0.46	0.34	0.37	0.36	0.70
III	Catla	0.04	0.10	0.11	0.20	0.33	0.50	0.50	1.34	1.11	0.77
	Rohu	0.07	0.06	0.21	0.23	0.30	0.67	0.40	0.17	0.70	0.53
	Mrigal	0.05	0.19	0.26	0.61	0.43	0.70	1.31	0.93	1.20	1.14
	C×R	0.09	0.14	0.31	0.24	0.26	0.57	0.55	0.92	0.94	0.52
	C×M	0.12	0.20	0.15	0.16	0.20	0.33	0.74	0.39	0.41	0.49
	R×M	0.02	0.14	0.23	0.17	0.18	0.35	0.58	0.94	0.51	1.09

1.49 g in September, 0.74 g in July and 0.92 g in August where the lowest values of the same species were recorded as 0.06 g in January, 0.04 g in January and 0.07 g in February 2008, respectively.

Different growth parameters of pure fish species in experiment I are presented in Appendix VI. The initial weight, the final weight, the average weight gain day^{-1} of catla was found higher than those of other two species. The net production (kg ha^{-1}/10 months) of pure catla, rohu and mrigal in experiment I was recorded as 307.71±1.15, 223.26±1.73 and 280.01±2.89 kg, respectively (Appendix VI). The survival rate of catla, rohu and mrigal was 43.75, 63.89 and 76.39%, respectively and it was significantly different ($p<0.01$) from each other. Although the survival rate of catla was lower than those of rohu and mrigal it had the highest net production (kg ha^{-1} 10 months) in experiment I (Appendix VI).

Growth, production and survival rate of hybrids in experiment II: The average growth of fishes in weight (g) in experiment II at different months is shown in Appendix IV. The initial average weight (g) and final average weight (g) of catla×rohu, catla×mrigal and mrigal×rohu were 395.13±2.89, 177.87±1.15, 200.53±5.73 and 604.33±2.31 g, 289.07±1.15, 306.27±1.73 g, respectively (Table 3-6). Average weight gain (g day^{-1}) of catla×rohu, catla×rigal and mrigal×rohu

Table 3: Identification of pure species

Species	Catla	Mrigal	Rohu
Shape	Deep body	Slender body	Not so deep as catla and not Body so slender as mrigal
Mouth	Upturned, the end of the mouth is nearly perpendicular to the iris, angle between lower part and upper part of the head is lesser than for mrigal and rohu	Mouth inferior, the end of the mouth is nearly perpendicular to the beginning of the eye, angle between lower part and upper part of the head is similar to rohu	Lower lip fringed, angle between lower part and upper part of the head is similar to mrigal
Lateral line	Strongly curving from the upper part of the operculum and to the beginning of the dorsal fin	Slightly curving from the upper part of the operculum and looks more like a straight line	Curving more than mrigal but less than catla
Barbels	No. barbels	Difficult to detect barbels on the upper jaw in fingerling stage but may be present later in life	No. barbels

Table 4: Identification of hybrids

Hybrid	Catla × mrigal	Catla × rohu	Mrigal × rohu
Body shape	More slender body, similar to rohu	Rather deep body but more slender than catla	Similar to rohu
Mouth	Slightly upturned but not so pronounced as catla and not at all so big, mouth opening smaller than catla	Mouth a bit upturned and opening smaller than catla, the end of the mouth is nearly perpendicular to the beginning of the eye. Upper lip thicker than catla and covers the lower lip. It is looking like rohu but no fringed lips	Upper lip thicker than for mrigal and covers the lower lip. It is looking like rohu but no fringed lips
Lateral line	Quite similar to mrigal, nearly no bending	Slightly curving from the upper part of the operculum and looks more like a straight line	Quite similar to mrigal, nearly no bending
Barbels	No barbels	No barbels	No barbels

Table 5: Meristic characters of Indian major carps and their hybrids

Characteristics	Catla	Rohu	Mrigal	C×R	C×M	M×R
Transverse scale on lateral line	$6_{1/2}$-$7_{1/2}$	$6_{1/2}$-$7_{1/2}$	$6_{1/2}$	$6_{1/2}$-$7_{1/2}$	$6_{1/2}$-$7_{1/2}$	$6_{1/2}$
Transverse scale under lateral line	$4_{1/2}$-$5_{1/2}$	$5_{1/2}$	$5_{1/2}$	$5_{1/2}$	$5_{1/2}$	$5_{1/2}$
Scale on lateral line	41	41-42	43-44	41-43	41-42	41-44
Dorsal fin ray	16-18	14-16	14	14-16	14-16	13-16
Pectoral fin ray	13-16	14-16	14-16	15-16	16	15-16
Pelvic fin ray	9	9	9	9	9	9
Anal fin ray	7	7-8	7	6-8	6-9	6-7
Caudal fin ray	19	18- 20	19- 20	19	19-20	19-20
Branchial ray	3-4	3	3	3	3	3

at different months in experiment II is shown in Appendix V. The highest weight gain day^{-1} of catla×rohu, catla×mrigal and mrigal×rohu was observed 1.30, 1.01 and 0.70 g, respectively in August. The lowest values of the same hybrids were recorded as 0.14, 0.03 and 0.07 g, respectively in January.

Different growth parameters of hybrids in experiment II are presented in Appendix VI. The initial weight, the final weight, the final weight gain (g) of catla×rohu was found higher than those of other two hybrids. The net productions (kg ha^{-1}/10 months) of hybrids catla×rohu,

Table 6: Different ratios of some morphometric characters for identification of Indian major carps and their hybrids

Different ratios (%)	Catla	Rohu	Mrigal	C×R	C×M	M×R (%)
FL/TL	85.12	88.65	86.91	88.37*	84.25	84.71
SL/TL	78.03	79.05	80.00	77.87	68.20	78.73
HL/TL	28.41	23.67	20.13	25.47*	20.47*	21.98*
Pre DD/TL	24.82	21.38	18.34	23.95*	20.97*	18.55*
Pre DL/TL	38.54	37.40	36.19	37.06*	29.28	35.91
CD/TL	11.16	10.80	9.97	11.57	10.67*	10.98
DBL/TL	20.03	17.95	15.55	17.47	17.54*	15.82*
ML/HL	33.97	25.22	29	25.45*	26.08	22.31
Gill/Head	65.39	67.90	59.87	59.88	58.99	57.90
Upper jaw/Lower jaw	1.24	1.25	1.47	1.48	1.40*	1.54

FL: Frok length, SL: Standard length, HL: Head length, Pre DD: Pre dorsal depth, PDL: Pre dorsal length, CD: Caudal depth, DBL: Dorsal base length,

Appendix VI: Growth performance of juvenile Indian major carps and their hybrids in experiment I, II and III during the experimental period

Exp. No.	Fish	Average initial wt. (g)	Average final wt. (g)	Average wt. gain (g)	Specific growth rate (% SGR day)	Survival (%)	Species wise production (kg ha^{-1}/10 months)	Net production (kg ha^{-1}/10 months)
I	Catla	291.07±0.58	469.05±5.77	177.97±1.15	0.16	43.75	307.71±1.15	810.98±24.85
	Rohu	230±2.89	347.9±1.73	117.9±1.73	0.41	63.89	223.26±1.73	
	Mrigal	198±1.54	321.67±1.15	123.67±5.77	0.16	76.39	280.01±2.89	
II	C×R	395.13±2.89	604.33±2.31	209.2±1.15	0.14	79.01	551.17±1.15	961.91±118.64
	C×M	177.87±1.15	288.07±1.15	110.2±2.89	0.16	69.14	254.05±5.77	
	R×M	200.53±5.78	306.27±1.73	105.73±0.57	0.14	46.15	156.69±1.15	
III	Catla	440.20±2.89	588.27±1.15	148.53±1.15	0.1	46.67	171.20±5.77	951.42±39.70
		321.2±0.57	422.67±2.30	101.50±0.57	0.09	85.42	171.32±1.15	
	Rohu	255.6±1.5	464±1.15	208.43±1.15	0.2	81	334.6±2.30	
		Mrigal	340.1±5.7	472.60±5.7	132.53±1.5	0.11	80	
			180±5.7	278.13±1.15		0.14	53.33	130.94±1.15
	C×R	201.6±1.5	97.23±1.15					
	C×M		64.04±0.58					
	R×M		330.03±2.89	128.40±1.5	0.16	62.5	79.29±1.73	

Value in the different supercripts in the same raw are significantly ($p<0.01$) different. *Sampling error (±SE) of treatment means calculated from rsidual mean square in the analysis of variance (ANOVA)

catla×mrigal and mrigal×rohu in experiment II were recorded as 551.17±1.15, 254.05±5.77 and 156.69±1.15 kg, respectively (Appendix V). The survival rate of catla×rohu, catla×mrigal and mrigal×rohu were 79.01, 69.14 and 46.15%, respectively and these rates were significantly different ($p<0.01$) from each other. The survival rate of catla×rohu was higher than those of catla×mrigal and mrigal×rohu and it also showed the highest net production (kg ha^{-1}/10 months) in experiment II (Appendix VI).

Growth parameters, production and survival rate of pure strains and their hybrids in experiment III: The average growth of fishes in weight (g) at different months is shown in Appendix IV. The initial average weight (g) of pure species and their hybrids were significantly different. The average initial weight (g) of pure species i.e., catla, rohu and mrigal were found as 440.20±2.89 g, 321.2±0.57 g and 255.6±1.5 g, respectively and the initial weight (g) of their hybrids i.e., catla×rohu, catla×mrigal and mrigal×rohu were observed as 340.1±5.7, 180±5.7 and

201.6±1.5 g, respectively. The final average weight (g) of the pure species and their hybrids were also significantly ($p<0.01$) different. The average final weights of catla, rohu and mrigal were 588.77±1.15, 464±1.15 and 422.67±2.50 g, respectively and the hybrids of catla×rohu, catla×mrigal and mrigal×rohu were 472.60±5.7, 278.13±1.5 and 330.03±2.89 g, respectively. The weight gain per day of catla, mrigal, catla×rohu, catla×mrigal and mrigal×rohu were found to be the lowest in January, where mrigal showed the lowest weight gain in February. The highest weight gain (g day^{-1}) of pure mrigal (1.31), catla (1.34) and rohu (0.70) were found in July, August and September 2008, respectively where their hybrids catla×mrigal, catla×rohu and mrigal×rohu showed the similar growth trend for July, September and October accordingly (Appendix V).

The growths of pure species and their hybrids in experiment III were tested by Duncan's Multiple Range Test (DMRT) and the result is presented in Appendix VI. The highest final weight gain (g) of mrigal was 208.43±1.15 g, followed by catla (148.53±1.15 g), catla×rohu (132.53±1.5 g), mrigal×rohu (128.40±1.5 g), rohu (101.50±0.57 g) and catla×mrigal (97.23±1.15 g).

The survival rate of pure species and their hybrids were significantly ($p<0.01$) different from each other except between pure mrigal and catla×rohu hybrid. The highest survival rate was obtained from rohu (85.42%) followed by mrigal (81) catla×rohu (80%), mrigal×rohu (62.50%), catla×mrigal (53.33), catla (46.67%). The survival rate of mrigal was second highest which resulted highest net production 334.62±2.30 kg ha^{-1}/10 months). In this experiment there was no significant difference in terms of net production was found between catla and rohu but significant ($p<0.01$) difference was obtained between the other pure species and their hybrids (Appendix VI).

Identification of pure species of the three Indian major carps and their hybrids: It is important to identify the fish at fingerling stage. By the fact, that carp species easily can cross breed and that unintended hybridisation occurs not only among the three species but also with other carp species e.g., mrigal x kuria labeo (*L. gonius*) and rohu x orange-fin labeo (*L. calbasu*), grass carp, kuria labeo and orange-fin labeo in the fingerling stage. However, grass carp has bigger scales, kuria labeo smaller scales and orange-fin labeo four. Other carps which may be mixed with the three Indian major carps may be silver carp, black carp etc. These other species may be a problem but for several of these it is possible to identify the fingerlings. The hybrids among the three Indian major carps are a much greater problem as intermediate or dominant traits really blurs their identification (Sarder and Simonsen, 2006).

Four major traits such as body shape, mouth, lateral line and barbels may be helpful for identification at fingerling size (3- 7 cm).

For identification of Indian major carps and their hybrids, it is also significant to know meristic and morphometric characters as shown in Table 5.

DISCUSSION

The growth performance, survival, production and some morphological differences of Indian major carps (*C. catla*, *L. rohita* and *C. cirrhosus*) and their hybrids (catla ×rohu, catla × mrigal and mrigal ×rohu) were investigated. Water quality parameters, soil quality parameters and abundance of plankton were considered as growth promoting factors. The net production basically depends upon growth and survival of species. Also other factors may associate with total production. In experiment I, the net production of catla was higher than those of other two species. In present study, catla was found to be the fastest growing species among Indian major carps which agreed with the reports by Jhingran and Pullin (1985). The records of weight gain per day of all the groups were found to be the highest in the month of June due to the higher temperature

(about 300°C) within the desirable range. Similar finding was reported by Dewan (1973), Mumtazuddin *et al.* (1982) and Islam (1997). Roy (2001) obtained the final average weight of catla 727 g whereas each of rohu and mrigal was 690 g in a year at stocking density 24 dec^{-1}In the present study, catla, rohu and mrigal achieved the final average weight of 177.97±1.154, 117.94±1.73 and 123.67±8.77 g, respectively where the stocking density was 40 per $deci^{-1}$. The results of the present study revealed the lower growth than that of the findings of Roy (2001). The higher stocking density in the present study was found to be the reasons of arresting growth due to the high competition of food and space. Supplemental diet and other inputs might not be the reason of such variations in growth, because the same feeding, fertilization, liming and other managements were provided to all the groups. The similar findings were reported by Alikunhi and Sukumaran (1964), Kawamoto *et al.* (1957) and Vaas-van Oven (1958) who observed that the higher the stocking density, the lower the growth performances. Powell (1972) reported the harmful effects of higher stocking density on fish culture, the reduction of growth rate and lowering of survival rate. The survival rate of fishes in the present study was 43.75-76.39% where Miah *et al.* (1997) found the survival rate from 89.23-99.23%.

The increase in body weight gain per day of all hybrids in experiment II was found to be high in the consecutive three months June, July, August and October 2008 due to high temperature. The average weight gain of individual catla × rohu was found higher (209.2±1.15 g) than those of catla × mrigal (110.2±2.89 g) and rohu × mrigal (105.73±0.57 g). Bhowmick *et al.* (1981) found the faster growth of hybrid catla×rohu than that of rohu only attaining a size of 900-035 g in one year. Chaudhuri (1971) mentioned that this hybrid attained a size of 718-915 g in a year under composite culture in freshwater ponds. The growth of three different hybrids in experiment II was different because of food competition among them. Reddy and Varghese (1980) observed the growth of catla×rohu hybrid in cisterns and found faster growth (63.3 g in 120 days) than that of rohu due to food competition.

The final average weight of pure species of catla, rohu and mrigal were 588.27±1.15, 422.67±2.30 and 464±1.15 g, respectively while the hybrids of catla×rohu, catla × mrigal and rohu×mrigal were 472.60±5.7, 278.13±1.13 and 330.03±2.89 g, respectively. The final average weight of pure species of catla, rohu and mrigal was 422.35, 296.74 and 240.12 g, respectively while the hybrids of catla×rohu, catla×mrigal and rohu×mrigal were 319.64, 169.80 and 185.83 g, respectively. Alikunhi *et al.* (1971) reported that catla♀ × rohu ♂ grew better than that of pure catla both in monoculture and polyculture system. They also observed that the growth of pure catla and catla♀×rohu♂ were 130 and 159 g, respectively during 6 months experimental periods in case of monoculture system where the initial weight of both of them was 31 g at the same stocking density (2500 ha^{-1}). In case of experiment III, the final average weight gained by catla and catla♀×rohu♂ were 385.94 and 304.58 g.

Among the three experiments the annual highest net production found in experiment II followed by experiment III and experiment I. The net production of experiment II and III were very close to each other. The net production of experiment III was higher than experiment I that was agreed with the findings of Ali *et al.* (1997) who reported the highest fish production from six species combination rather than three, four or five combinations in their experiment.

Several researchers worked on identification of hybrids of Indian major carps. Desai and Rao (1970), Chaudhuri (1973), Natarajan and Mishra (1976), Reddy and Varghese (1980) and Bhowmick *et al.* (1981) worked on catla×rohu, Basavaraju and Varghese (1980) on rohu×mrigal and mrigal×rohu and Gopal *et al.* (1989) worked on catla×mrigal and mrigal×catla.

All the authors found the intermediate taxonomic characters of hybrids with their parental species. For identification of hybrids, the present study was conducted with some selected taxonomic characters. Morphometric characters expressed in this study as percentages (%) with respect to total body length and head length for ease of identification. Results showed that, the percentages of HL/TL and pre DD/TL of all hybrids were intermediate in morphometric characters. The percentages of FL/TL, Pre DL/TL and ML /HL of catla × rohu, CD/TL of catla×mrigal and DBL/TL of mrigal × rohu also showed intermediate characters. These findings were found to be similar to that of the findings of previous authors. Other characters did not agree with intermediacy. It might be due to variation in the genetic potential or characteristics.

CONCLUSION

This study gives a clear concept that unintended hybridization should be avoided as it will cause a lesser production and can damage the purity of the species. Relatively little research has been carried out on the cyprinid genetic resources in Bangladesh. However, research is underway on a number of most important species and it is hoped that improved stocks from selective breeding programmes will be utilized in aquaculture in the near future. Fish genetic manipulation, selection and biodiversity conservation are of paramount importance in the country and the Government authorities are actively considering establishing a National Center of Fish Genetics Resources and Biodiversity Conservation that will also go a long way in supplementing the global efforts for conserving fish biodiversity.

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