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Evaluation of growth performance of amur common carp (*Cyprinus carpio*) and mrigal (*Cirrhinus mrigala*) with major carps in polyculture system

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Abstract
The present experiment was conducted in rectangular cemented tanks (5 x 4 x 1m) each for five months to evaluate growth performance of amur common carp (*Cyprinus carpio*) and mrigal (*Cirrhinus mrigala*) with major carp in polyculture system. The experiment included three treatments in triplicates *viz*. T1: mrigal, catla (*Catla catla*), rohu (*Labeo rohita*), silver carp (*Hypophthalmichthys molitrix*) and silver barb (*Puntius gonionotus*) at 6:3:6:2:3; T2: amur common carp, catla, rohu, silver carp and silver barb at 6:3:6:2:3; and T3: mrigal, amur common carp, catla, rohu, silver carp and silver barb at 3:3:3:6:2:3. Results showed that mean weight gain and specific growth rate of mrigal and amur common carp were higher in T3 compared to T1 and T2 and that of silver carp was significantly (P<0.05) higher in T2 than T1 and T3. Net gain biomass, daily weight gain and net fish yield in T2 and T3 were significantly higher than T1. The highest net gain biomass, daily weight gain and net fish yield were obtained in T3 followed by T2 and T1. No significant differences in survivability (%) were observed among treatments. The result demonstrated that amur common carp performs better than mrigal with major carps in polyculture system and with stocking a ratio of 15% each have an improved fish production.

Keywords: Amur common carp, mrigal, carp polyculture, growth performance

Introduction

In India, about 85% of the total aquaculture production is contributed by the carps. Laxmappa (2014) [1] has reported that major production in India is contributed by three Indian major carps including *Catla catla, Labeo rohita* and *Cirrhinus mrigala*. In addition, many other medium as well as minor carps have been successfully incorporated into carp polyculture systems in India over the years using different methods as these fishes have consumer's demand and higher market value and also comparable growth potential in different region of the country. Carps are found to be the dominant fish species in aquaculture system in Southern Asia [2]. It has also been accepted that in carp polyculture system, the most popular fish species are *Labeo rohita* (rohu), *Catla catla* (catla) and *Cirrhinus mrigala* (mrigal) [3, 4]. Though, rohu at present is very popular among the farmers because of its high market value and consumer preference [5], yet many farmers are disappointed with rohu due to their slow growth rate and the complexity of managing them in a polyculture system [6]. Stocking densities suggested higher yields when rohu was cultured with common carp [7].

Cyprinus carpio, an improved strain of wild common carp of Hungarian origin is known as amur common carp [8, 9]. The amur common carp has greater practical significance in low-input aquaculture systems due to its better growth performance than the existing strain. Amur common carp was received from Fisheries Research and Information Center, Bengaluru, which was supplied to College of Fisheries, Central Agricultural University, Tripura for further study. The selection of a suitable benthivorous fish can increase nutrient flux, which greatly influences the abiotic and biotic properties of the overlying water column [10]. The comparative studies between amur common carp and mrigal on the effects on water quality, nutrient accumulations and food intake and fish growth are absent. Therefore, in the present study the effects of mrigal and amur common carp were compared to evaluate growth, survival and yield of fish with major carps in polyculture system.

Materials and Methods

Experimental tanks and their preparation

A series of 9 rectangular outdoor cement tanks of 20 m^2 (5 x 4 x 1 m) each at the College of Fisheries, Lembucherra, Tripura, India were utilized. Tank bottoms were filled with about 6 inches of the soil bed. All the tanks were completely independent having facility of water supply from ground water source. Tanks were drained and sun dried for one week before application of lime. Dried tanks were applied with lime at 500g $Ca(OH)_2$ $tank^{-1}$ at the rate of 250 kg ha^{-1} and then filled with water from ground water source. All tanks were fertilized one week after liming with cow dung at the rate of 5 kg $tank^{-1}$.

Experimental set up and design

The three treatments performed were, Treatment 1 (T1): mrigal, catla, rohu, silver carp and silver barb at 6:3:6:2:3; Treatment 2 (T2): amur common carp, catla, rohu, silver carp and silver barb at 6:3:6:2:3; and Treatment 3 (T3): mrigal, amur common carp, catla, rohu, silver carp and silver barb at 3:3:3:6:2:3. The average initial size of catla, rohu, mrigal, silver carp, amur common carp and puntius were 22.76, 16.79, 5.03, 15.83, 8.18, 21.61 g, respectively. Each of the experimental tanks was stocked with 40 fish, which were collected from the fish farm of College of Fisheries, Lembucherra, Tripura, India.

Fertilization of tanks was done weekly in the morning with urea and single super phosphate at the rate of 60 g $tank^{-1}$ and fortnightly with an organic fertilizer such as cow dung (500 g $tank^{-1}$). The required amounts of fertilizers were dissolved and were sprayed over the whole surface area.

Sinking pelleted feed with crude protein level of 20% was formulated with locally available feed ingredients including wheat flour, corn flour, mustard oil cake, rice bran and fish meal and feed was prepared from automatic extruder using 2 mm dia. Fishes were fed at 2-4% of body weight of fish and feeding was done once daily at 09:00-10:00 h and amount of feed was adjusted after fortnightly sampling of fish during the experiment.

To monitor the growth performance of fishes, following parameters were used.

Specific growth rate (%/day) = 100 x [Ln (Final weight) – Ln (Initial weight)] / Culture period (day).

Net fish yield (g m^{-2} d^{-1}) = [Total fish biomass at harvest – Total fish biomass at stock] / Area* culture period.

Daily weight gain (g d^{-1}) = (Total final weight – Total initial weight) / Culture period

Survival rate (%) = (Final total numbers /Initial total numbers) × 100.

Water sampling was done fortnightly and the parameters were transparency (cm), water temperature (°C), pH, dissolved oxygen (mg l^{-1}), total alkalinity (mg l^{-1}), hardness (mg l^{-1}), PO_4-P (mg l^{-1}), NO_3-N (mg l^{-1}) and NO_2-N (mg l^{-1}) were recorded and estimated. For the analysis of water quality, water samples were collected from each tank from the surface depth of 20 cm. Temperature and DO were recorded fortnightly by using Thermometer and Winkler's Method, respectively. pH were measured fortnightly by pH meter. Transparency was measured fortnightly with a Secchi disk. Ammonia-Nitrogen was estimated by Phenate method. Alkalinity and hardness were estimated by titrimetric method. Phosphate, Nitrite-Nitrogen and Nitrate-Nitrogen was estimated by [10].

Statistical Analysis

All statistical analysis was performed using Statistical Package for Social Sciences (SPSS, version 16.0 for windows). Analysis of variance (One way - ANOVA) was performed to determine the differences between the mean values. The tests for differences was done by using Duncan's Multiple Range Tests (DMRT) at $P<0.05$ level.

Results and Discussion

Water quality parameters

The physico-chemical parameters of water in the experimental tanks were recorded fortnightly throughout the experiment and presented in Table 1. All the water quality parameters were found to be within the acceptable ranges for carp culture during the experimental period. Although, some fluctuations in water quality parameters were recorded during the experiment, the ranges were suitable for fish culture. The water temperature in the treatments, during the culture period varied between 14-24.73 ^{0}C and found suitable for growth of common carp [11]. During the experiment, water pH varied between 7.23-8.49 in all treatments and thus suitable for fish growth and survival [12]. The dissolved oxygen (DO) content in all treatments ranged from 5.01 to 6.61 mg l^{-1}, which was favorable for the growth of fish [13]. In the present study, alkalinity was recorded in the range of 86.33-90.67 mg l^{-1} which is in the acceptable range for fish culture. Variation in alkalinity was not very high and these few changes might be due to the exchanging of water. Hardness was in the range of 110-144 mg l^{-1} which was within the range of suitable for fish growth and survival [14]. The increased in ammonia and nitrite contents with the progress of culture were attributed to the fertilization and gradual accumulation of metabolites and uneaten feed [15-17,] whereas, decreased level of ammonia may be due to additional uptake of ammonia by periphyton which led to its reduced level in all treatments. However, inorganic nutrients such as nitrite (0.23-0.42 mg l^{-1}), nitrate (0.42-1.93 mg l^{-1}) and phosphorus (0.16-0.28 mg l^{-1}) were within the acceptable ranges for polyculture [18].

Table 1: Ranges of different physico-chemical parameters of water for the different treatment during the culture period

Parameters	Treatments		
	T1	T2	T3
pH	7.23-8.49	7.31-8.18	7.47-8.00
Transparency (cm)	16.0-72.3	16.0-57.7	14.3-57.3
Temperature (^{0}C)	14.0-24.4	14.0-24.6	13.9-24.7
Dissolved Oxygen (mg l^{-1})	5.0-6.2	5.3-6.2	5.4-6.6
Alkalinity (mg l^{-1})	90.7-114.7	86.7-109.3	87.3-114.0
Hardness (mg l^{-1})	110.0-136.7	113.3-144.0	110.0-134.0
Ammonia (mg l^{-1})	0.55-0.64	0.55-0.64	0.59-0.68
Nitrate (mg l^{-1})	0.42-1.84	0.85-1.93	0.67-1.70
Nitrite (mg l^{-1})	0.24-0.34	0.23-0.42	0.27-0.35
Phosphate (mg l^{-1})	0.17-0.27	0.16-0.28	0.19-0.27

Fish Growth Performance

The initial mean weight (g), final mean weight (g) and mean weight gain (g) of different fish species under different treatments are given in Table 2. Mean weight gain of amur common carp was found to be significantly higher ($P<0.05$) in T3 compared to T2. The higher mean weight gain of amur common carp in T3 might be due to the less inter-species competition for preferred natural food as it had less stocking density of amur common carp compared to T2. Another possible reason might be due to dominancy of amur common carp in feed consumption over the other fishes. This finding is in accordance with the results reported [19] where they showed that growth of amur common carp was faster over the existing stock of common carp. However, in the initial period of the experiment, the growth rate of amur common carp in both the treatments took place at a slower rate which was probably due to lower temperature. Similar results were also observed [20, 21] who reported that water temperature is the only variable that affect significantly the growth rate of Indian major carps.

Higher mean weight gain (g) of mrigal was found in T3 in compared to T1, but did not differ significantly (P>0.05). From the present results, it is evident that growth of mrigal is slow in comparison to amur common carp. In addition, the present study revealed that the mean weight gain of amur common carp was highest in T3 compared to other treatments. This might be due to the more availability and effective utilization of macrophytes in T3 than other treatments, which acts as food for the omnivorous fish like common carp. Another possible reason could be the symbiotic effect of both amur common carp and mrigal. The possible reason could also be due to burrowing behavior of amur common carp which results in the release of nutrients from pond bottom and increase the productivity and at the same time, it also releases obnoxious gasses from the bottom consequently results the better yield. However, the mean weight gain of mrigal in T3 was significantly lower than that of amur common carp. This might be due to the presence of silver carp which feeds on phytoplankton thus reduces the availability of phytoplankton and results less precipitation of plankton on to the bottom where mrigal mainly feed. The alternative reason for lower growth of mrigal could be explained by the disturbances of bottom and not allowing any kind of detritus due to the burrowing nature of amur common carp. This effect was not felt by the common carp, since this species does not feed on phytoplankton in the water column and can feed on the bottom browsing in deeper layers than mrigal. This is in accordance with work [22] who reported that mrigal is a bottom feeder that feeds on detritus, plants and zooplankton but also migrates throughout the water column to feed.

Table 2: Initial mean weight, final mean weight and mean weight gain (g) ± S.E. of different species in different treatments for 150 days culture period

Species	Culture period	Treatments		
		T1	T2	T3
Catla	Initial	22.83±2.87	15.89±2.15	29.55±1.44
	Final	136.34±9.26	127.83±16.03	119.25±11.11
	Mean weight gain	113.50±11.08	119.94±29.33	89.69±11.05
Rohu	Initial	16.14±0.66	17.03±0.31	17.19±0.06
	Final	80.33±21.90	80.75±2.74	86.66±0.00
	Mean weight gain	64.19±22.56	63.72±2.80	69.46±0.05
Mrigal	Initial	5.33±0.22	-	4.72±0.15
	Final	38.47±6.27	-	41.70±3.14
	Mean weight gain	33.14±6.09	-	36.97±3.24
Silver	Initial	15.42±0.42	16.33±0.30	15.57±0.57
	Final	66.89±11.42^a	96.50±1.45^b	65.00±0.00^a
	Mean weight gain	51.47±11.00^a	80.16±1.56^b	49.25±0.52^a
Amur common carp	Initial	-	7.36±0.50	9.00±0.25
	Final	-	181.73±24.84	346.20±38.2
	Mean weight gain	-	174.37±24.83	337±38.17
Silver barb	Initial	22.61±0.64	20.39±0.89	21.83±1.42
	Final	110.09±31.63	77.12±17.06	82.43±2.18
	Mean weight gain	87.47±17.73	56.72±10.74	60.59±2.54

Values are mean ± standard error. Values in the same row with same superscripts are not significantly different (P>0.05)

No significant differences (P>0.05) were observed in mean weight gain of catla, rohu and silver barb in different treatments. However, mean weight gain of silver carp was significantly (P<0.05) higher in T2 compared to T1 and T3. Catla final mean weight gain performance showed large variability among ponds that resulted in non-significant treatment effects. Thus, the apparent better catla growth in T1, followed by T2 and T3, respectively, should be considered only a trend. It was indicated that neither bottom-feeder fish nor addition of silver barb, significantly affected performance of catla. Catla is a surface feeder mainly capturing zooplankton [23, 24]. Zooplankton abundance and composition were similar in common carp and mrigal ponds. So, catla did not benefit from the phytoplankton enhancement produced by the common carp activity, which instead was utilized by rohu. The trend of higher catla growth in mrigal ponds, might be related to phytoplankton composition, hence of secondary importance to have a significant effect on a fish eating phytoplankton only as complementary food. From the phytoplankton, catla positively selects diatoms [25, 26] which was more abundant in mrigal ponds, in which catla have performed better.

The comparative higher final mean weight gain rohu could be explained by common carp stirring up mud bottom while feeding, thus improving nutrient recirculation. This, in turn, favours phytoplankton development in the water column, on which rohu feeds [24, 25, 6]. The phenomenon of nutrient release as a result of stirring effects of common carp in the pond bottom was well documented [27, 28, 6]. Similarly, growth of silver barb was higher in T1 followed by T3 and T2. The final mean weight gain of silver carp was higher in T2 compared to T1 and T3. This effect could be due to the searching for food, common carp produces a stronger stirring on the mud bottom than mrigal [29, 30] increasing water turbidity and facilitating nutrient flow through the autotrophic food web. Thus, in common carp ponds there were more phytoplankton that absorbed more nutrients and the overall respiration in the pond was higher than in mrigal ponds. Together with this, grazing by silver carp on phytoplankton maintained the algae populations continually reproducing, thus absorbing more nutrients and increasing biomass as compared with populations in ponds without this fish.

Mean specific growth rates (SGR) of individual species under different treatments during the period are presented in Table 3. No significant differences (P>0.05) in specific growth rate (SGR) of rohu, mrigal, amur common carp and silver barb were observed in different treatments. But, significantly (P<0.05) highest SGR values of catla and silver carp were observed in T2. This might be due to the distinct differentiation of the feeding regime from the amur common carp which feed mainly on benthic fauna and decaying vegetable matter whereas catla is an efficient utilizer of artificial feed and natural food resources feed mainly on zooplankton [31]. The SGR of amur common carp and mrigal showed an increasing trend towards T3 might be due to the mutual benefit of burrowing nature of amur common carp resulting better primary productivity.

Table 3: Species wise mean specific growth rate (SGR) ± S.E. for different treatments during the culture period

Species	Treatments		
	T1	T2	T3
Catla	1.20±0.04^{ab}	1.39±0.16^{b}	0.93±0.08^{a}
Rohu	1.03±0.20	1.04±0.03	1.08±0.00
Mrigal	1.30±0.09	-	1.45±0.07
Silver carp	0.96±0.09^{a}	1.18±0.02^{b}	0.95±0.02^{a}
Amur common carp	-	2.13±0.10	2.43±0.07
Silver barb	1.04±0.10	0.88±0.11	0.89±0.06

Values are mean ± standard error. Values in the same row with same superscripts are not significantly different (P>0.05)

The mean growth parameters including net gain biomass, daily weight gain, net fish yield and survival of whole biomass is given in Table 4. The survival, net gain biomass are the functions of inter-specific compatibility of the carp species in culture tanks [14]. The significantly (P<0.05) highest final biomass was obtained in T3 and lowest value was obtained in T1. The net gain biomass (NGB) in T3 followed by T2 and were significantly (P<0.05) higher than T1. Similarly, daily weight gain (DWG) of fish in T3 followed by T2 were significantly (P<0.05) higher than T1. In the same trend, Net fish yield (NFY) in T3 and T2 were significantly (P<0.05) higher compared to T1. The lowest values of final biomass, NGB, DWG and NFY in T1 might be contributed by slower growth rate of mrigal. The highest biomass obtained at the end of the experiment in T3 where mrigal and amur common carp were stocked in equal proportion retaining other species in similar rate, though DWG value was similar with T2. Several factors might be responsible for this such as better feed utilization of amur common carp, contribution towards improved primary productivity through burrowing nature of amur common carp, efficient utilization of available artificial feed and natural resources by all the fish species, better sharing of food regime among species [32].

The survivability percentages of fish did not show any significant differences (P>0.05) among the treatments. Similar survival in carps was reported by several earlier studies reported in polyculture [15-17, 33, 14]. However, lower survivability in T2 compared to T1 and T3 was found which could be interpreted as lower survivability of amur common carp due to the more intra-specific competition and voracious feeding habit than mrigal and other species. In T3 the survivability was higher due to compatibility among species. The Comparative higher survivability in T1 might be due to the less nutrient requirements of mrigal compared to amur common carp. Silver barb survival seems to be related to interactions with the larger fish. As the large bottom feeders, silver barb feed on the bottom and on detritus [34]. The turbidity produced by the common carp activity near the bottom might have negatively affected silver barb survival, possibly through gill clogging. On the other hand, silver carp is a very efficient filter feeder [27] and in its presence less particles sediment on to the tank bottom preventing detritus enrichment. Thus, in carp tank silver carp reduced the excess of particles re-suspended by carp allowing increased survival of silver barb, while in mrigal tanks, silver carp grazing decreased food availability for the bottom feeders, reducing silver barb survival. The outcome of the present work demonstrated that amur common carp could be incorporated as an alternative species in combination with mrigal in major carp polyculture system and with stocking a ratio of 15% each of the species would improve fish production.

Table 4: Mean growth parameters ± S.E. for different treatments during the culture period

Parameters	Treatments		
	T1	T2	T3
Initial biomass (g)	592.0±19.7	575.7±18.6	660.0±19.1
Final biomass (g)	1787±147^{a}	2844±203^{b}	3526±313^{b}
Net gain biomass (g)	1195±145^{a}	2268±202^{b}	2866±309^{b}
Daily weight gain (g d^{-1})	7.97±0.97^{a}	15.12±1.35^{b}	19.11±2.06^{b}
Net fish yield (g m^{-1} d^{-1})	0.40±0.05^{a}	0.76±0.07^{b}	0.96±0.10^{b}
Survival (%)	60.00±5.77	51.67±3.00	64.17±1.67

Values are mean ± standard error

Values in the same row with same superscripts are not significantly different (P>0.05)

Conclusion

This study indicated that the overall performance in terms of growth, survival, feed utilization of amur carp is better than mrigal and if both are stocked at the ratio of 15% each are more profitable and economically feasible in carp polyculture system

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