GROWTH, SURVIVAL RATE, AND NUMBER OF MARKETABLE FISH PRODUCED OF GOLD FISH, *CARASSIUS AURATUS* (L.) IN OUTDOOR EARTHEN PONDS WITH ENDOGENOUS CULTURE OF *DAPHNIA* SP. OR *MOINA* SP. AND EXOGENOUS SUPPLY OF MIXED PLANKTON

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Abstract

The effect of different management systems on the growth and survival of gold fish in ponds was investigated. Fish larvae (0.11 ± 0.012 g) were cultured for three months. There were four treatments: fish were stocked in outdoor ponds under endogenous culture of Moina sp. (P1), Daphnia sp. (P2), exogenous supply of mixed plankton (P3) and a control treatment where a commercial pellet was applied as food (P4). Values of dissolved oxygen were highest in the P3 ($p<0.05$). The P4 treatment showed the highest concentrations of NH_4-N, NO_2-N, NO_3-N, PO_4-P, and bicarbonate alkalinity, which were significantly higher ($p<0.05$) than the other treatments. The final body weight of the gold fish ranged from 3.78 to 7.19 g in the different treatments. At harvest, maximum weight gain was achieved in the P3, followed by P2, P1 and P4 in descending order ($p<0.05$). There was a significant difference ($p<0.05$) in the survival of gold fish among the treatments, ranging from 75.77% (P4) to 97.54% (P3). The number of marketable fish was significantly higher in P3 ($p<0.05$) than other treatments. From the present investigation, exogenous supply of mixed plankton appeared to be a better alternative to culturing goldfish in ponds under endogenous culture of Moina sp. or Daphnia sp.

Key words: gold fish, feed, plankton, growth, survival

INTRODUCTION

The world export and import values of ornamental fish in the year 2010 were US $ 337082558 and US $ 155090001, respectively [4]. Overall it is a continuously growing industry [24]. The culture technology for exotic ornamental fish under tropical conditions in India needs to be standardized if India were to become a major player in the international ornamental fish market [7]. Carps like koi, *Cyprinus carpio* L. and goldfish, *Carassius auratus* (L.) can be easily reared in ponds and although there are some papers on koi culture techniques [10,11,13,16,17], barring a few papers [14,19,27], there is a paucity of documentation on goldfish growth under outdoor pond conditions in India.

Exogenous introduction of live plankton (mixed species) substantially enhanced weight gain and reduced mortality in ornamental carps cultured in outdoor tanks and ponds [12,15,16,17]. In an earlier experiment [14], the cladoceran *Moina* was found to be the most abundant plankton (21.86%) in the gut contents of goldfish under a 1:1 polyculture combination with koi carp, while *Daphnia* was the most abundant plankton under monoculture (35.10%). In the present study, the effect of feeding goldfish with *Moina* sp. was compared with feeding *Daphnia* sp. and a diet of mixed plankton.

MATERIAL AND METHOD

Two- to three-week old larvae of goldfish, *Carassius auratus* (L.) (0.11 ± 0.012 g) were acclimatized in 24 outdoor concrete tanks (capacity: 2000 L) for 1 week prior to the experiment. Fish were cultured

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for three months (5 July to 3 September' 2011). There were four treatments: fish were stocked in ponds under (1) endogenous culture of *Moina* sp. (P1); (2) endogenous culture of *Daphnia* sp. (P2); and (3) exogenous supply of mixed plankton (P3). A control treatment was also present where a commercial pellet (Tokyu Corp., Japan; containing 32% crude protein) was applied as feed (P4).

For the Treatments P1 and P2, the pond-bottom soil was sun-dried prior to the experiment to which lime was added @ 0.2 kg lime per ton soil. Poultry manure was added to the ponds on the 4th day at a rate of 0.26 kg/m^3 to promote phytoplankton blooms. Cladocerans can utilize much of the manure directly in the form of detritus. On day 12, the ponds were fertilized a second time with poultry manure (0.52 kg/m^3). Thereafter, weekly fertilization rates are maintained at 1.04 kg/m^3. The inoculation of the ponds was carried out on the 15th day at a rate of 10 *Moina* (P1) or 10 *Daphnia* (P2) per litre.

Fish were stocked at 1.5 fish/l (89425 fish/pond) as optimized in an earlier experiment [9]. There were three replicates for each treatment. The fish were observed carefully and fed daily slightly in excess of satiation in P3 and P4 to eliminate the possibility of food supply being a limiting factor to growth. A single layer of plastic bird netting was used to cover the ponds. Constant water levels were maintained in the ponds by supplying ground water periodically to compensate for loss due to evaporation. Approximately 1000 l of excess water was discharged from the P3 ponds every day during the introduction of live plankton-water. A plankton cloth was tied over the outflow water pipe to prevent any loss of zooplankton during the process. The ponds used for culturing plankton were fertilized with poultry manure at 0.26 kg/m^3at the beginning and subsequently once in every10 days [13].

Water samples were collected from the ponds once a week. The concentrations of nutrients (PO_4-P, NH_4-N, NO_3-N, NO_2-N) and routine water quality parameters (free CO_2, alkalinity, dissolved oxygen) were analysed according to methods as described by APHA [2]. pH was measured in situ using a portable pH meter (Hanna Instruments, Rua do Pindelo, Portugal). Temperature was recorded by a centigrade thermometer. Samples of plankton were collected in plankton net made of standard bolting silk cloth (No. 21 with 77 mesh/ cm^2) once a week. Collected plankton samples were concentrated to 20 ml, and preserved in 4% formalin. Enumerations of 1 ml of concentrated plankton were performed under a stereoscopic microscope using Sedgewick Rafter Counting Cell.

For growth rate assessments, individual fish weights were recorded both at the beginning and during harvest. Twenty five hundred fish were randomly collected from each pond and weighed individually to the nearest 0.001 g. For this, the fish were anaesthetized with 0.04 g/l of tricaine methane sulphonate (MS-222). Among these 2500 fish, the number and percent of fish with body deformities were recorded. Dead fish were removed daily and were not replaced during the course of study, and differences between the number of fish stocked and the number of fish at harvest were used to calculate percent mortality in each treatment. Data were normalized using angular transformation [22]. The specific growth rate (SGR; %/ day) for each treatment was calculated as: SGR = 100 [(ln W_t − ln W_0) / t]; where W_0 and W_t are the initial and final live weight of the fish (g), respectively, and (t) is culture period in days [25].

A one-way ANOVA procedure was performed to detect significant differences in water quality parameters as well as growth, survival, SGR and deformities in each fish species among treatments. A Tukey's test [29] was used to compare and rank means. A level of significance of $p < 0.05$ was used. The number of marketable fish at the end of growth period was calculated using the function for a normal distribution curve, where $z = (y-\mu)/\sigma$; y is the lowest marketable weight (g), μ is the mean weight of the population, σ is the standard deviation of the total weight and z follows the standard normal probability distribution which determines the probability of finding fish above a given range. The number of marketable fish (n) was then determined using the table value of the normal probability distribution (P) as follows: n = (1-P)* h; h is total number of fish produced minus deformed or damaged fish.

RESULTS AND DISCUSSIONS

The plankton abundance and species diversity were dissimilar in the different treatments. Cladocerans were in higher abundance in the environment compared to copepods in P1, P2 and P3 (Figure 1). Copepods were more abundant in P4, however, it should be pointed out that fish stocked in P4 also had supplemental diet that was not provided in the other treatments. Among cladocerans, *Moina* was overwhelmingly dominant in P1, *Daphnia* was overwhelmingly dominant in P2, while *Moina* and *Daphnia* were equally dominant (there was no significant differences between the numbers of *Moina* and *Daphnia*) over *Bosmina* in P3 (Figure 2).

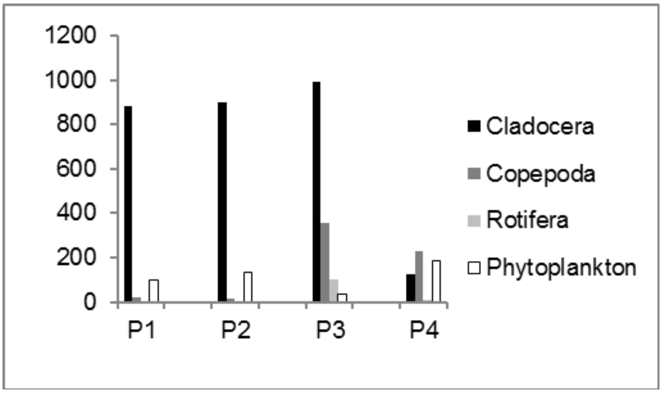

Figure 1 Plankton abundance (no./l) in the different experimental ponds

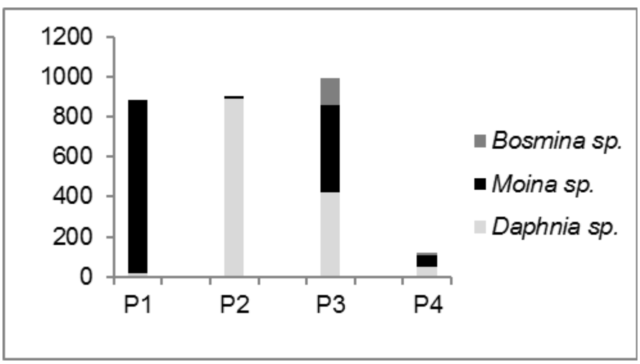

Figure 2 Cladoceran abundance (no./l) in the different experimental ponds

Water temperature was between 25ºC and 35ºC during the 3-month growth period. However, there was no difference in the water temperature between the different treatments on any particular sampling date. Values of dissolved oxygen were highest in the P3, followed by P4, P2 and P1 ($p<0.05$; Table 1). The P4 treatment showed the highest concentrations of NH_4-N, NO_2-N, NO_3-N, PO_4-P, free CO_2 and bicarbonate alkalinity, which were significantly higher ($p<0.05$) than the other treatments (Table 1).

The final body weight of the gold fish ranged from 3.78 to 7.19 g in the different treatments (Table 2). At harvest, maximum weight gain was achieved in the P3, followed by P2, P1 and P4 in descending order ($p<0.05$; Table 2). There was a significant difference ($p<0.05$) in the survival of gold fish among the treatments (Table 2), ranging from 75.77% (P4) to 97.54% (P3). The number of fish with deformities was significantly higher in P4 ($p<0.05$) than other treatments (Table 2). To determine the output of marketable fish, the percentage and number of fish exceeding a total weight of 5 g was estimated from the size-frequency distribution at the end of the study. The number of marketable fish was significantly higher in P3 ($p < 0.05$) than other treatments (Table 3).

Table 1 Summary of water quality parameters analyzed for the four treatments at weekly intervals during the 3-month growth period

Parameters	Treatment			
	P1	P2	P3	P4
pH (range)	5.5 – 7.5	5.5 – 7.5	6.5 – 8.0	4.2 – 7.2
Dissolved oxygen (mg/l)	4.72 ± 0.44 [c]	4.65 ± 0.36 [c]	7.17 ± 0.20 [a]	6.11 ± 0.21 [b]
Free CO_2 (mg/l)	2.77 ± 0.16 [b]	2.70 ± 0.14 [b]	1.03 ± 0.13 [c]	3.44 ± 0.42 [a]
Total alkalinity (mg/l)	127.90 ± 13.13 [b]	131.90 ± 18.12 [b]	46.83 ± 07.49 [c]	160.39 ± 21.34 [a]
PO_4 – P (mg/l)	0.411 ± 0.28 [b]	0.405 ± 0.18 [b]	0.085 ± 0.13 [c]	0.450 ± 0.11 [a]
NH_4 – N (mg/l)	0.406 ± 0.31 [b]	0.397 ± 0.28 [b]	0.051 ± 0.05 [c]	0.496 ± 0.16 [a]
NO_2 – N (mg/l)	0.193 ± 0.15 [b]	0.198 ± 0.19 [b]	0.048 ± 0.04 [c]	0.255 ± 0.30 [a]
NO_3 – N (mg/l)	0.344 ± 0.34 [b]	0.354 ± 0.39 [b]	0.132 ± 0.09 [c]	0.476 ± 0.51 [a]

Means with different letter as superscript are significantly different ($p < 0.05$)

Table 2 Growth performance, survival, deformities and number of marketable fish estimated in goldfish after rearing in earthen ponds under different management regimes for 3- months

Parameters	Treatment			
	P1	P2	P3	P4
Initial body weight (g ± SE)	0.11 ± 0.012 [a]	0.11 ± 0.012 [a]	0.11 ± 0.012 [a]	0.11 ± 0.012 [a]
Harvest weight (g ± SE)	6.66 ± 0.07 [c]	6.90 ± 0.05 [b]	7.29 ± 0.10 [a]	3.78 ± 0.25 [d]
Weight gain (g ± SE)	6.55 ± 0.07 [c]	6.79 ± 0.05 [b]	7.18 ± 0.10 [a]	3.67 ± 0.25 [d]
Specific growth rate (% / day)	4.56 ± 0.05 [c]	4.60 ± 0.06 [b]	4.66 ± 0.09 [a]	3.93 ± 0.09 [d]
Survival (%)	85.14 [b]	86.03 [b]	97.54 [a]	75.77 [c]
Deformed individuals (%)	2.20 [b]	1.67 [c]	2.22 [b]	7.50 [a]

Data in the same rows with different superscripts are significantly different ($p < 0.05$)

Table 3 The average number of marketable goldfish (those heavier than 5.0 g) produced, together with marketable fish produced expressed as a percentage of number of fish stocked (A) and as a percentage of total number of fish produced* (B) in the different treatments

Treatment	Number of fish stocked (fish $pond^{-1}$)	Number of marketable fish produced* (fish $pond^{-1}$)	Marketable fish (%)	
			(A)	(B) *
T1	89475	73553 [c]	82.21	99.11
T2	89475	75422.81 [b]	84.29	99.92
T3	89475	85024 [a]	95.03	99.69
T4	89475	69.89 [d]	0.08	0.11

* Excluding deformed fish
Different superscripts in a column represent statistically significant differences ($p < 0.05$)

Zooplankton contributes to faster larval growth and better survival in most cultured fish [1,12,16,26]. In an earlier experiment [14], the cladoceran, *Moina* was found to be the most abundant plankton (21.86%) in the gut contents of goldfish under a 1:1 polyculture combination with koi carp and the second most abundant plankton under monoculture (28.25%). *Daphnia* was the most abundant plankton under monoculture (35.10%) [14]. However, in the present study, goldfish cultured in P3 (with exogenous supply of mixed plankton) compared better that those cultured in P1 (under endogenous culture of *Moina* sp.) and P2 (under endogenous culture of *Daphnia* sp.).

Daphnia is a frequently used food source in the freshwater larviculture (i.e. for different carp species) and in the ornamental fish industry [20]. *Moina* is of a smaller size than *Daphnia*, with higher protein content [20]. Produced biomass of *Moina* sp. has been successfully used in the larviculture of rainbow trout, salmon, striped bass and by tropical fish hobbyists [20].

However, goldfish possibly avoided *Moina* when offered an optimal monoculture condition, as evidenced from electivity index estimates from an earlier experiment, even though it was the second most abundant plankton (28.25%) in the gut content analysis [14]. The goldfish even showed better weight gain in the monoculture condition (where *Daphnia* was the most abundant plankton in gut analysis), compared to polyculture, where they were perhaps forced to take more of *Moina* along with other plankton like copepods and rotifers under stiff competition for food from koi carp that it could avoid in monoculture [14].

In such monoculture, where a mixed plankton diet was available, the goldfish selected a mixed cladoceran diet of *Daphnia*, *Moina* and *Bosmina* [14]. The diet in the P3 treatment of the present experiment was similar. Studies on feeding behaviour and food selection of koi carp and goldfish [12,14] indicated a strong preference for mixed cladocerans under optimal culture conditions. Linear relationship between the weight gain of koi carp and cladoceran abundance also exhibited a high correlation ($r = 0.958$; $p<0.01$) [15].

Higher weight gain, SGR and survival rate of goldfish in the P3 treatment ($p < 0.05$) could be attributed to the improved water quality, expressed in terms of lower values of ammonium and nitrite, and higher values of DO and pH, which is conducive to fast reproduction of some of the major zooplankton constituting the main food item of carps [6], and also due to the regular introduction of live plankton.

Plankton intake of planktivorous fishes varies with different feeding conditions. It has been reported the plankton intake of common carp, *Cyprinus carpio* in the live food system was higher than in manured or control system [5].

Nitrite enters a fish culture system after feed is digested by fish and the excess nitrogen is converted into ammonia, which is then excreted as waste into the water. Total ammonia nitrogen is then converted to nitrite which, under normal conditions, is quickly converted to nitrate by naturally occurring bacteria [3]. Uneaten (wasted) feed and other organic material also break down into ammonia, nitrite, and nitrate in a similar manner [3]. Higher values of NH_4-N, NO_2-N, NO_3-N, PO_4-P, free CO_2 and bicarbonate alkalinity in the P1, P2 and P4 treatments, compared to P3 ($p < 0.05$) could be attributed to the regular application of poultry manure or supplementary pelleted feed in the ponds. Nitrite levels should be kept below 0.05 mg/L in goldfish culture systems [28] and in our experiment, only P3 treatment had mean nitrite concentrations below that level. That the fish growth and survival was better in P1 and P2, compared to P4 was due to the presence of live food in P1 and P2 and is in agreement with earlier studies with koi carp [12,15,16,17].

Water temperature was between 25°C and 35°C during the growth period; possibly it did not affect the differential growth of fish between the treatments in our experiment. Goldfish, along with koi carp, are considered “robust” fish because they can survive in poor water quality [28]. However, for optimal growth, appearance, reproduction and health, maintaining good water quality is essential. Their optimum temperature range is about 18 to 24°C [28]. In an earlier experiment, koi carp was cultured for 11-weeks during four growth periods throughout the year to study the effect of water temperature and seasonal differences on the growth of fish. Water temperature averaged

18.6, 29.7, 28.2 and 26.5°C during the winter, summer, monsoon and post-monsoon trials respectively, and growth was highest in the summer-trial, when temperatures were the highest [16].

Significantly higher percentage of deformed goldfish in the control treatment could be attributed to the commercial diet applied in the treatment. Similar results were obtained with crucian carp, *Carassius carassius* when fed with commercial diets [23] and with koi carp [16]. According to a report [21], skeletal and other deformities are associated with nutritional deficiencies or imbalances and are rarely observed in ponds in the presence of live food. The results from the probability distribution table (Table 3) indicate that stocking goldfish in P3 yielded the highest number of marketable fish. P1 and P2 also yielded much better results than P4 (Table 3). In contrast to food fish production, where producers focus primarily on the total number of fish produced [8,18], ornamental fish can only be sold when they have reached a particular size (5 g).

CONCLUSIONS

From the present investigation, exogenous supply of mixed plankton appeared to be a better alternative to culturing goldfish in ponds under endogenous culture of *Moina* sp. or *Daphnia* sp. This could be attributed to improved water quality, which is contributing to fast reproduction of some of the major zooplankton (mixed cladoceran diet) constituting the preferred food item of goldfish. Further research on husbandry management of goldfish needs to be conducted.

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