Research Article

Evaluation of different water exchange regimes for optimizing growth and production of koi carp, *Cyprinus carpio* in tanks

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Abstract: The effect of different water exchange regimes on the growth and survival of koi carp, *Cyprinus carpio* in tanks provided with the supply of exogenous zooplankton as the food was investigated. Fish larvae (0.15±0.012g) were stocked in outdoor concrete tanks at 0.5 fish/l (T1 and T2); 1.0 fish/l (T3 and T4); and 1.5 fish/l (T5 and T6) and cultured for three months. The water exchange rate was 10% once daily in T1, T3 and T5 and twice daily in T2, T4 and T6. Values of dissolved oxygen were highest in T2, followed by T4, T1, T6, T3 and T5. The T5 treatment showed the highest concentrations of conductivity, NH$_4$-N, NO$_2$-N, NO$_3$-N, PO$_4$-P, and bicarbonate alkalinity, which were significantly higher than the other treatments. The final body weight of *C. carpio* ranged from 4.01 to 8.22g in the different treatments. At harvest, maximum weight gain was achieved in the T2, followed by T4, T1, T6, T3 and T5 in descending order. There was a significant difference in the survival of koi carp among the treatments, ranging from 56.43% (T5) to 96.32% (T2). The percentage and number of fish exceeding a total weight of 5g were estimated from the size-frequency distribution at the end of the study and was significantly higher in T6 ($P<0.05$) than other treatments. From the present study, a daily water exchange of 20% could support higher stocking densities of koi carp in tanks and result in high productivity, measured in terms of the number of marketable fish.

Keywords: Aquaculture management, Ornamental carp, Fish production, Water quality.

Introduction

Animal manure has been traditionally employed by culturists in India and neighbouring countries to augment the production of plankton, a natural food item for fish (Chakrabarti & Jana 1998; Gupta & Noble 2001; Jha et al. 2004). However, using high amounts of animal manure can reduce the water quality (Boyd 1982; Singh et al. 1991) and thereby result in stress and impairment of normal metabolism in fish leading to fatigue, disease, and high mortality (Francis-Floyd 1990).

Ornamental fish, unlike food fish, are sold individually and have to be visually attractive to be accepted in the market, and stressed fish may be aesthetically unattractive to potential customers (Jha & Barat 2005a). Hence, particular pond management techniques need to be developed to create the best environment for the fish.

Since most farmers in India cannot afford high-cost recirculating systems or aeration, manual water exchange in production tanks has been the only viable alternative to intensify production in ornamental fish culture units (Jha et al. 2004; Jha & Barat 2005a). On average, about 65.71% farmers in neighboring Bangladesh exchange water regularly in their ponds (Shofiquzzoha et al. 2017). An exchange of 5% of standing water volume from the tanks every day resulted in high production of koi carp, *Cyprinus carpio* Linnaeus, 1758 stocked at a density of 0.2 fish/L with a direct application of poultry manure (Jha & Barat 2005a) and 0.3 fish/L with application of a pellet diet (Jha & Barat 2005b).
Ornamental fish farming has been subjected to a variety of experimentation to increase yields and profitability (Jha 2007). Exogenous introduction of live plankton (mixed species) substantially enhanced weight gain and reduced mortality of ornamental fish in some of our earlier experiments, while maintaining better water quality standards, compared to application of organic manure or pellet diet (Jha & Barat 2005c; Jha et al. 2006, 2007, 2008; Jha 2017). According to Jha (2010), under such conditions, the stocking density could be increased up to 1.0 fish/L for the rainbow shark, *Epalzeorhynchus frenatus* (Fowler, 1934). Here, the water exchange rate was 10% of the standing water volume from the tanks, once every day. Water exchange helps in maintaining water quality as it flush the excess phytoplankton and toxic metabolites not assimilated by the phytoplankton, thereby minimizing diurnal fluxes in dissolved oxygen (Chamberlain 1987). It was hypothesized that if the water exchange rate could be optimized, the water quality could be further enhanced to support a greater stocking density. In the present study, the effect of different water exchange regimes on the growth, survival and number of marketable fish produced of koi carp, *Cyprinus carpio* reared in outdoor concrete tanks at different stocking densities was compared.

**Materials and Methods**  
Koi carp larvae of the same parental stock were obtained from the hatchery of Rainbow Ornamental Fish Farm, Raninagar, Jalpaiguri, India and acclimatized in 24 outdoor concrete tanks (L×W×H: 2.13×0.91×1.22m; capacity: 2000L) for 1 week prior to the experiment. The culture experiments were also conducted on the same fish farm. The guidelines for experimentation under the “Breeding of and Experiments on Animals (Control and Supervision) Rules, 1998” (amended during 2001 and 2006) of the Govt. of India were adhered during experimentation.

About three-week old fish larvae (0.15±0.012g) were cultured for three months (02 March to 31 May’ 2011) under six treatment regimes in 18 outdoor concrete tanks (size and capacity mentioned above), and maintained at stocked densities of 0.5 fish/l (T1 and T2); 1.0 fish/l (T3 and T4); and 1.5 fish/l (T5 and T6). There were three replicates for each treatment. The water exchange rate was 10% (of the total volume in a tank) once daily in T1, T3, and T5, and twice daily in T2, T4, and T6.

A single layer of plastic bird netting was used to cover the tanks. Constant water levels were maintained in the tanks by supplying ground water periodically to compensate for the loss due to evaporation. Exogenous plankton (freshly collected and of mixed nature) was applied at 20% body weight of stocked fish once daily in all the treatments. This higher dose of food application was due to the fact that the plankton was wet and contained moisture. Fish were fed slightly in excess of satiation to eliminate the possibility of the food supply being a limiting factor to growth.

The ponds used for culturing the plankton were fertilized with poultry manure at 0.26kg/m³ at the beginning and subsequently once every 10 days (Jha et al. 2004). Plankton samples were collected with a plankton net made of standard bolting silk cloth (No. 21 with 77 mesh/cm²) once a month from the plankton culture ponds. Collected plankton samples were concentrated to 20ml and preserved in 4% formalin. The plankton abundance and species diversity in the plankton culture ponds (Table 1) give an impression of the plankton that was actually available for the fish in the culture tanks. Cladocerans were in higher abundance (41.99%), compared to copepods (38.34%), rotifers (12.85%) and phytoplankton (6.82%).

Water samples were collected once a week at 9:00 hrs. Water quality parameters were estimated according to standard methods as described by APHA (1998). pH was measured in situ using a portable pH meter (Hanna Instruments, Rua do Pindelo, Portugal). The temperature was recorded by a centigrade thermometer. Individual fish weights were recorded both at the beginning of the experiment and during harvest. Five hundred fish
were randomly collected from each tank and weighed individually to the nearest 1mg. For this, the fish were anesthetized with 0.04g/l of tricaine methane sulphonate (MS-222). Dead fish were removed daily, they 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 the percentage of mortality in each treatment. Percentages of final survival and deformities were normalized using angular transformation (Mosteller & Youtz 1961) before being subjected to further statistical analysis. The specific growth rate (SGR; %/ day) for each treatment was calculated as SGR = 100 [(ln Wt – ln W0) / t]; where W0 and Wt are the initial and final live weight of the fish (g), respectively, and (t) is culture period in days (Ricker 1975).

A one-way ANOVA procedure was performed to detect significant differences in water quality parameters as well as growth (wet weight), survival, SGR and deformities among treatments. A Tukey’s test (Zar 1999) 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-μ)/σ; 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 a total number of produced minus deformed or damaged fish.

**Results**

There were noticeable differences in water quality among the treatments (Table 2). Water temperature was 21-34°C during the 90 days. Values of dissolved oxygen were highest in the T2, followed by T4, T1, T6, T3 and T5 (P<0.05; Table 2). The T5 treatment showed the highest concentrations of conductivity, NH4-N, NO2-N, NO3-N, PO4-P, and bicarbonate alkalinity, which were significantly higher (P<0.05) than the other treatments. The final body weight of koi carp ranged from 4.01 to 8.22g in the different treatments (Table 3). At harvest, maximum weight gain was achieved in the T2, followed by T4, T1, T6, T3 and T5 in descending order (P<0.05). There was
Table 2. Mean±Standard Error of water quality parameters (in mg/l) analyzed for the six treatments at weekly intervals during the 3-month growth period. Means with a different letter as superscript are significantly different (P<0.05).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treatments</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (range)</td>
<td></td>
<td>6.5±0.03</td>
<td>6.7±0.01</td>
<td>6.1±0.01</td>
<td>6.4±0.01</td>
<td>6.1±0.01</td>
<td>6.2±0.01</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td></td>
<td>7.02±0.32 b</td>
<td>7.99±0.30 a</td>
<td>5.14±0.11 e</td>
<td>7.33±0.39 b</td>
<td>4.57±0.44 f</td>
<td>6.34±0.30 d</td>
</tr>
<tr>
<td>Free CO₂</td>
<td></td>
<td>2.19±0.26 b</td>
<td>1.03±0.14 c</td>
<td>3.27±0.27 ab</td>
<td>1.89±0.25 bc</td>
<td>3.97±0.67 a</td>
<td>3.11±0.44 ab</td>
</tr>
<tr>
<td>Total alkalinity</td>
<td></td>
<td>110.69±11.53</td>
<td>41.80±6.21 e</td>
<td>155.09±15.12</td>
<td>80.11±4.14 d</td>
<td>176.25±10.06</td>
<td>72.15±6.15</td>
</tr>
<tr>
<td>PO₄ - P</td>
<td></td>
<td>0.22±0.35 d</td>
<td>0.05±0.05 f</td>
<td>0.43±0.17  b</td>
<td>0.11±0.27 c</td>
<td>0.51±0.10 a</td>
<td>0.32±0.16 c</td>
</tr>
<tr>
<td>NH₄ - N</td>
<td></td>
<td>0.29±0.44 d</td>
<td>0.06±0.04 f</td>
<td>0.56±0.05 b</td>
<td>0.15±0.5 e</td>
<td>0.76±0.14 a</td>
<td>0.36±0.21 c</td>
</tr>
<tr>
<td>NO₂ - N</td>
<td></td>
<td>0.13±0.08 bc</td>
<td>0.02±0.06 d</td>
<td>0.17±0.11 ab</td>
<td>0.07±0.012 e</td>
<td>0.21±0.05 a</td>
<td>0.15±0.17 b</td>
</tr>
<tr>
<td>NO₃ - N</td>
<td></td>
<td>0.24±0.40 c</td>
<td>0.12±0.11 d</td>
<td>0.32±0.15 b</td>
<td>0.19±0.2 cd</td>
<td>0.45±0.23 a</td>
<td>0.30±0.16 bc</td>
</tr>
</tbody>
</table>

Table 3. Growth performance, survival, and deformities estimated in koi carp after rearing in different treatments for 3 months. Data in the same rows with different superscripts are significantly different (P<0.05).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treatments</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial body weight (g±SE)</td>
<td></td>
<td>0.15±0.012 a</td>
<td>0.15±0.012 a</td>
<td>0.15±0.012 a</td>
<td>0.15±0.012 a</td>
<td>0.15±0.012 a</td>
<td>0.15±0.012 a</td>
</tr>
<tr>
<td>Final body weight (g±SE)</td>
<td></td>
<td>6.5±0.09 e</td>
<td>8.22±0.12 a</td>
<td>4.62±0.07 e</td>
<td>7.09±0.06 b</td>
<td>4.01±0.16 d</td>
<td>5.9±0.12 d</td>
</tr>
<tr>
<td>Weight gain (g±SE)</td>
<td></td>
<td>6.3±0.09 e</td>
<td>8.07±0.12 a</td>
<td>4.7±0.07 e</td>
<td>6.9±0.06 b</td>
<td>3.8±0.16 d</td>
<td>5.8±0.12 d</td>
</tr>
<tr>
<td>Survival (%)</td>
<td></td>
<td>81.75±0 b</td>
<td>96.3±4 a</td>
<td>68.25±4 d</td>
<td>85.5±b</td>
<td>56.4±3 a</td>
<td>75.15±5 a</td>
</tr>
<tr>
<td>Deformed individuals (%)</td>
<td></td>
<td>4.10±c</td>
<td>2.3±3 b</td>
<td>11.9±0 c</td>
<td>7.2±d</td>
<td>23.7±5 b</td>
<td>16.8±b</td>
</tr>
</tbody>
</table>

Table 4. The average number of marketable koi carp (those heavier than 5.0g) produced, together with marketable fish produced expressed as a percentage of the number of fish stocked (A) and as a percentage of total number of fish produced* (B) in the different treatments.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of fish stocked (fish/pond)</th>
<th>Number of marketable fish produced* (fish/pond)</th>
<th>Marketable fish (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>1000</td>
<td>761.45 d</td>
<td>76.15</td>
</tr>
<tr>
<td>T2</td>
<td>1000</td>
<td>939.95 c</td>
<td>93.99</td>
</tr>
<tr>
<td>T3</td>
<td>2000</td>
<td>93.21 e</td>
<td>4.66</td>
</tr>
<tr>
<td>T4</td>
<td>2000</td>
<td>1565.99 ab</td>
<td>78.30</td>
</tr>
<tr>
<td>T5</td>
<td>3000</td>
<td>17.33 f</td>
<td>0.58</td>
</tr>
<tr>
<td>T6</td>
<td>3000</td>
<td>1640.31 a</td>
<td>54.68</td>
</tr>
</tbody>
</table>

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

a significant difference (P<0.05) in the survival of koi carp among the treatments, ranging from 56.43% (T5) to 96.32% (T2). The percentage of fish with deformities was significantly higher in T5 (Table 3). To determine the output of marketable fish, the percentage and number of fish exceeding a total weight of 5g were estimated from the size-frequency distribution at the end of the study. Although 99.99% of all the fish harvested in the T2 and T4 tanks could be marketed, compared to 93.79% in T6, in terms of total numbers, the number of marketable fish was significantly higher in T6 (P<0.05) than the other treatments (Table 4).

Discussion
For the tanks maintained under any particular stocking density, significantly lower dissolved oxygen concentrations and higher free CO₂, PO₄-P, NH₄-N, NO₂-N, and NO₃-N concentrations could be observed with low rate of water exchange (T1, T3, and T5 treatments), compared to the treatments with higher water exchange (T2, T4, and T6). In an earlier experiment, a lack of water exchange significantly reduced the water quality in koi carp ponds (Jha & Barat 2005a). According to Hopkins et al. (1993), both water exchange rates and stocking density influenced the water quality parameters in intensive
shrimp ponds.

Accumulating water quality concentrations within low exchange water recirculation aquaculture systems can negatively impact cultured species (Deviller et al. 2005; Davidson et al. 2009, 2011; Martins et al. 2009a, 2009b). There is increasing evidence which put forward the view that even low NO₃-N concentrations that were earlier considered to be harmless (Colt & Tomasso 2001; Colt 2006), could cause chronic toxicity to various species (Hamlin 2005; Van Bussel et al. 2012; Davidson et al. 2014). Good et al. (2009) reported high mortality in rainbow trout *Oncorhyncus mykiss* (Walbaum, 1792) cultured in a recirculation aquaculture system with low water flushing.

An increase in the nitrite content in pond water could lead to considerable stress on the fish resulting in a decreased growth rate, tissue damage, and mortality (Lewis & Morris 1986). An adverse impact of nitrite is the oxidation of haemoglobin to methaemoglobin (Kroupova et al. 2005), which reduces the total oxygen-carrying capacity of the blood (Cameron 1971). Fish having higher stores of glycogen in the liver and can derive a greater portion of their energy requirement from anaerobic glycolysis. Lowering their requirement for oxygen, they may cope with elevated levels of methaemoglobin for longer periods (Perrone & Meade 1977). Compared to adult fish, larvae and juveniles have considerably lower amount of glycogen stores in the liver (Coban & Sen 2011). In our experiment, lower growth of fish larvae in the T5, T3 and T6 treatments could be affected by the higher nitrite levels. A negative effect of nitrite exposure on common carp respiration and growth has been reported by Korwin-Kossakowski & Ostaszewska (2003).

Unionized ammonia is also regarded as highly poisonous to fish (Arillo et al. 1981). Although unionized ammonia was not measured in the current experiment, according to Sinha et al. (2012), the toxic effects of ammonia exposure to aquatic animals strongly occur in high concentrations of unionized ammonium because it can readily diffuse through the gill membranes. In the current study, the average NH₄-N in T5 was 0.768mg/l, when the pH was in the range of 5.5-7.8 and the temperature was between 21-34°C. Under these conditions, the percentage of NH₃ in the water was estimated to be about 2% of the NH₄-N (Emerson et al. 1975), i.e. 0.015mg/l, which is below the threshold limit of 0.44mg/l. However, according to Parma de Croux & Loteste (2004), even an incidental increase in the pH to more than 8.0 in such a situation could lead to high mortality due to a significant increase in NH₃ toxicity. One concern with high levels of water exchange is that it could flush out nitrifying bacteria resulting in reduced nitrification and increased ammonia concentrations (Milstein et al. 2001). However, in our experiment, under any particular fish stocking density, the treatments with higher water exchange (T2, T4 or T6) recorded significantly lower NH₄-N concentrations, compared to the treatments with lower water exchange (T1, T3 or T5).

The water quality of the fish pond influences the protein conversion efficiency in fish. Under reduced water quality parameters, the fish are stressed and this affects the utilization of the protein in the diet (Ajiboye et al. 2015). Perhaps the significantly high level of nutrients along with low dissolved oxygen concentration in the T5 and T3 treatments lowered the grazing activity of the carp and is in agreement with earlier results (Jha et al. 2004, 2008; Jha & Barat 2005a). Ponds with high water exchange rates will tend to produce bigger fish compared to ponds with limited or no water exchange, due to poor water quality and lack of dissolved oxygen that can breakdown the ammonia released through excretion (Nkengayi 2011). Increased mortality might also arise due to reduced feed intake when water quality is not of optimal quality (Asano et al. 2003). These factors probably influenced the low growth and survival rates of koi carp in the T5 and T3 treatments.

The percentage of marketable fish could be considered reasonable in tanks with high water exchange (T2, T4 and T6), and a combination of low
stocking density with low water exchange (T2). The stocking density influenced the growth rate and mortality. In fact, the growth and survival were higher in T2, T4, and T1 (in descending order), compared to the other treatments (both T1 and T2 had the low stocking densities). A combination of higher stocking density and low water exchange resulted in higher mortalities (T5).

Fish stocking density is a very important factor determining the productivity of a culture system (Kaiser et al. 1997). At a low stocking density and before attainment of carrying capacity, the fish grow properly and stocking density does not affect fish growth (Ronald et al. 2014). This probably explains the high growth rates in the T1 and T2 treatments. However, the density should be the resultant value of the environmental requirements of a given species and broadly understood economic efficiency (Holm et al. 1990; Szkudlarek & Zakes 2002). Since the number of marketable fish was significantly higher in T6 (1640.31) and T4 (1565.99), compared to the other treatments, it could be suggested that the higher stocking densities could be applied, in combination with a higher water exchange rate. Whether the T6 was a more economically efficient treatment, compared to the T4 or vice versa could be argued in terms of the procuring rate of the fish larvae (3000 larvae were stocked in each T6 pond, compared to 2000 larvae in the T4) and the wholesale rate of a 3-month old fish (about 84 additional marketable fish was produced in the T6 tanks, compared to T4); and these rates may vary around the world.

From the present study, it appeared that a daily water exchange of 20% could support higher stocking densities of koi carp in tanks and result in high productivity, measured in terms of the number of marketable fish. Further research on the effect of different frequency of water exchange in ornamental fish tanks needs to be conducted.

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مقاله پژوهشی

ارزیابی رژیم‌های مبادلاتی متفاوت آب برای بهبود سازی رشد و تولید کپور معمولی، Cyprinus carpio

در مخازن

برنوریاج چاپ

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چکیده: تاثیر رژیم‌های مبادلاتی آب بر رشد و بقاء کپور معمولی، Cyprinus carpio در مخازن تأمین شده با زئوپلانکتون برون زاد به عنوان منبع غذایی مورد بررسی قرار گرفت. لاروهای ماهی (0/12/0 ± 15/0 گرم) در مخازن بتونی خارجی به صورت 1/0/1/0 (T1 و T2) به صورت دوبار در روز بود. مقادیر ذخیره، و به‌مدت سه ماه پوره داده شدند. ترتیب مبادله آب 10 درصد در T1، T2، T3 و T5 به صورت دو بار در روز بود. محلول به‌ترتیب در T2، T4، T6 و T5 بیشترین غلظت رسانایی، N4-NO2، N3-NO3، N2-NH3، P4-PO4 و نیترات قلیایی را نشان داد که به‌طور معنی‌داری از موارد دیگر بیشتر بود. در نهایی بند کپور معمولی در موارد مختلف از 0/1/4 تا 22/0/8 گرم متغیر بود. در برداشت، بیشترین وزن حاصل به‌ترتیب در T2، T4، T6 و T5 به‌دست آمد. تفاوت معنی‌داری در بین کپورهای متغیر در این موارد سریا بود. در مورد بررسی شده مشاهده کرد که از 0/1/4 درصد (T5) تا 4/3/8 درصد (T2) متغیر بود. در مورد تعداد ماهی فراوانی از وزن کل 5 گرم در پایان مطالعه، از توزیع افتاده خواصی تخمین زده شد و به‌صورت معنی‌داری در از موارد دیگر بیشتر بود. با توجه به مطالعه حاضر، میزان روند آب 20 درصد می‌تواند تراکم های استوکی بالاتری از کپور معمولی را در مخازن حمایت کند و می‌تواند منجر به تولید بیشتر بر حسب تعداد ماهی قابل فروش شود.

کلمات کلیدی: مدیریت آبی، بیشتر، کپور معمولی، کپوریت، آب.