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EFFECT OF WATER EXCHANGE ON WATER QUALITY AND THE PRODUCTION OF ORNAMENTAL CARP (*CYPRINUS CARPIO* VAR. *KOI* L.) CULTURED IN CONCRETE TANKS MANURED WITH POULTRY EXCRETA

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ABSTRACT. The effect of water exchange on water quality, plankton abundance, and the production of koi carp, *Cyprinus carpio* var. *koi* L., cultured in outdoor concrete tanks manured with poultry excreta was determined. Individual weight gain and survival rates of fish (initial weight 0.09 ± 0.02 g) were compared among five culture regimes, where a volume of 100 dm^3 water was exchanged: (1) every day (WE1); (2) every alternate day (WE2); (3) two times a week (WE3); (4) once a week (WE4); and (5) a control treatment with no water exchange (NE). Significantly higher concentrations ($P < 0.05$) of conductivity, NH_4-N, NO_2-N, NO_3-N, PO_4-P and bicarbonate alkalinity were recorded in the NE treatment. Plankton volume was highest in WE1 ($P < 0.05$). The weight gain and number of koi carp of marketable size were significantly higher ($P < 0.05$) in WE1. There was a significant difference in the survival of koi carp among the treatments ranging from 60.43% (NE) to 95.21% (WE1). The results suggest a water exchange of 100 dm^3 daily (WE1) was the most effective for koi carp tanks manured with poultry excreta as better water quality and greater plankton abundance were both maintained in the system.

Key words: KOI CARP (*CYPRINUS CARPIO* VAR. *KOI*), WATER EXCHANGE, WATER QUALITY, PLANKTON ABUNDANCE, FISH PRODUCTION

INTRODUCTION

Production of animals for the aquarium hobbyist trade is growing rapidly. The annual global trade has increased from US$ 4.5 billion in 1995 to about US$ 9 billion in 2002 (Swain and Jena 2002). Establishing an ornamental fish culture industry has long been felt to be one means to diversify the aquaculture sector in India.

In the case of food fish culture, the intensification of natural production is stimulated through fertilization or organic manuring in ponds (Moore 1985). Since biological

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productivity is often limited by nutrients, pond fertilization is of great importance to supplement nutrient deficiency and augment aquatic productivity through autotrophic and heterotrophic pathways (Green et al. 1989, Schroeder et al. 1990, Knud-Hansen and Batterson 1994). However, pond fertilization using high amounts of manure can lead to water quality deterioration, including the severe depletion of dissolved oxygen, high biological and chemical oxygen demand, and high ammonia levels (Boyd 1982). Primary production in excessively fertilized ponds can limit light penetration (Hepher 1962). The resultant stress can ultimately lead to exhaustion, disease, and mortality in fish (Francis-Floyd 1990). Moreover, ornamental fish, unlike food fish, are sold by number and have to be visually attractive to be accepted in the market, and stressed fish may be aesthetically unattractive to potential customers. In light of these factors, particular pond management techniques need to be developed to create the best environment for the fish, while utilizing animal wastes that can sustain productivity at low cost.

Fertilization with manure with water exchange have proved to be more effective than manured systems without water exchange in maintaining better water quality and lower mortality rates in common carp, *Cyprinus carpio* L. (Chakrabarti and Jana 1990), Indian major carp rohu, *Labeo rohita* (Ham.), and mrigal, *Cirrhinus mrigala* (Ham.) (Chakrabarti and Jana 1998). The water quality management in the culture of ornamental fishes in Indian conditions remains to be elaborated.

The present study was conducted to compare the effect of different water exchange regimes on the growth and survival of ornamental fish in manured culture systems. Koi carp, *Cyprinus carpio* var. *koi* L., were used as a model species and poultry excreta was applied as a standard organic manure.

MATERIALS AND METHODS

ANIMALS

A total of 6000 two-week old koi carp larvae were obtained from a local fish farm (Rainbow Ornamentals, Raninagar, Jalpaiguri, India). The koi carp were the offspring of a mixed commercial production by 25 pairs of parents of the Kohaku, Bekko, and Asagi koi types. After a one-week acclimatization period, the koi carp of an initial weight of 0.09 ± 0.02 g (average BW ± SD; N = 50) were evenly distributed in 15 outdoor concrete tanks (capacity 2000 dm^3). The stocking density corresponded to 0.2 fish dm^{-3}, which is widely practiced in ornamental fish farms (Fernando and Phang 1985). All the tanks were manured every 10 days with poultry excreta applied at 0.26 kg m^{-3}, as standardized in an earlier experiment (Jha et al. 2004).

EXPERIMENTAL PROCEDURE

A 10 cm layer of soil was placed at the bottom of each tank, which was then filled with 2000 dm^3 of groundwater 10 days prior to stocking. A 3.175 cm GI pipe was fitted to the outlet of each tank in such a way that water in excess of 2000 dm^3 would automatically flow out. A plankton net (No. 21 with 77 mesh cm^{-2}) bordered the outlet preventing escape of plankton with the outflowing water. Five experimental groups were cultured, each in triplicate, for 90 days (June-August 2002): (1) 100 dm^3 water exchange once daily (WE1); (2) 100 dm^3 water exchange every alternate day (WE2); (3) 100 dm^3 water exchange two times a week (WE3); (4) 100 dm^3 water exchange once a week (WE4); and (5) a treatment without any water exchange (NE). A single layer of plastic bird netting was used to cover the tanks.

DATA COLLECTION

The amounts of total nitrogen and organic carbon in the poultry manure were estimated according to the Micro-Kjeldahl (Anderson and Ingram 1993) and Wet Oxidation methods (Walkley and Black 1934), respectively.

Water samples were collected weekly. Water quality parameters (dissolved oxygen, BOD, free carbon dioxide, total alkalinity, conductivity, ammonium, nitrite, nitrate, and phosphate) were estimated according to methods described by APHA (1998). pH was measured *in situ* using a portable pH meter (Hanna Instruments, Rua do Pindelo, Portugal). Temperature was recorded with a centigrade thermometer.

Samples of plankton were collected with a plankton net made of standard bolting silk cloth (No. 21) two times a week. The collected plankton samples were concentrated to 20 cm^3, preserved in 4% formalin, and counted under a stereoscopic microscope using a Sedgwick Rafter Counting Cell.

The body weight of the fish was recorded at the beginning of the experiment. At fortnightly intervals during the culture period, five random samples of 20 fish from each tank were netted and excess water removed on paper toweling through the net before the fish were weighed individually to the nearest ± 1 mg. For this, the fish were anaesthetized with tricaine methane sulphonate (MS-222) at a concentration of 0.04 g dm^{-3}. 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. Results in percentage were normalized using angular transformation (Sokal and Rohlf 1969) before being subjected to further statistical analysis. The fish were harvested after 90 days and weighed. The Specific Growth Rate (SGR) was calculated as: $SGR = 100\ [(\ln W_t - \ln W_0)\ t^{-1}]$; where W_0 and W_t are the initial and final body weight of the fish (g), respectively, and (t) is the culture period in days (Ricker 1975).

STATISTICAL ANALYSIS

The data on body weights, SGR, and survival rates were compared using one-way analysis of variance (ANOVA) and Tukey's HSD test (Zar 1996). The differences were considered statistically significant at the probability level of $P \leq 0.05$. The degree of linear relationship between plankton density and fish growth was determined by means of correlation coefficients following Karl Pearson's method (SunderRao and Richard 1999).

The number of marketable fish at the end of growth period was calculated using the function for a normal distribution curve, where $z = (y-\mu)\ \sigma^{-1}$; y is the least 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: $n = (1-P) \times$ total number of fish produced.

RESULTS

The amounts of total nitrogen and organic carbon in the poultry manure were 2.66% and 30.19%, respectively. Water temperature ranged between 24 and 35°C during the investigation period, whereas pH varied from 6.7-8.6 (Table 1). Higher water exchange rates increased the average dissolved oxygen in WE1 (7.94 mg dm^{-3}), which was significantly higher ($P < 0.05$) than the other treatments. In contrast, significantly higher ($P < 0.05$) BOD values were obtained in NE (4.63 mg dm^{-3}).

The NE 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 ($P < 0.05$) than the other treatments (Table 1). Carbonate alkalinity was observed only in the WE1, WE2, and WE3 treatments, for very limited periods, when the free CO_2 content in these treatments was absent. Within the different treatments with water exchange (WE1, WE2, WE3, and WE4), there were no significant differences ($P > 0.05$) between the average values of bicarbonate alkalinity, NH_4-N, NO_2-N, and specific conductivity (Table 1).

TABLE 1

Mean ± SE of the major water quality parameters analyzed for the five treatments at weekly intervals during the three-month growth period. Data in the same row with different superscripts are significantly different ($P < 0.05$)

Parameters	Treatment				
	WE1	WE2	WE3	WE4	NE
pH*	6.8 – 8.6	6.8 – 8.6	6.8 – 8.5	6.5 – 8.4	6.2 – 8.2
Dissolved oxygen (mg dm^{-3})	7.94 ± 0.32^{a}	7.37 ± 0.30^{ab}	6.91 ± 0.24^{bc}	6.08 ± 0.18^{c}	5.08 ± 0.26^{d}
Biological Oxygen Demand (mg dm^{-3})	1.23 ± 0.17^{c}	1.46 ± 0.23^{bc}	1.99 ± 0.36^{bc}	2.62 ± 0.28^{b}	4.63 ± 0.52^{a}
Free CO_2 (mg dm^{-3})	0.42 ± 0.15^{c}	0.49 ± 0.17^{c}	0.61 ± 0.20^{c}	1.86 ± 0.23^{b}	3.16 ± 0.46^{a}
CO_3 alkalinity (mg dm^{-3})	0.66 ± 0.17	0.60 ± 0.19	0.13 ± 0.13	-	-
HCO_3 alkalinity (mg dm^{-3})	95.19 ± 6.89^{b}	102.95 ± 8.42^{b}	110.07 ± 9.66^{ab}	115.5 ± 9.38^{ab}	146.25 ±11.02^{a}
PO_4 -P (mg dm^{-3})	0.226 ± 0.028^{b}	0.253 ± 0.031^{b}	0.294 ± 0.035^{b}	0.428 ± 0.061^{ab}	0.563 ± 0.080^{a}
NH_4 -N (mg dm^{-3})	0.163 ± 0.021^{b}	0.183 ± 0.025^{b}	0.202 ± 0.027^{b}	0.308 ± 0.044^{b}	0.753 ± 0.148^{a}
NO_2 -N (mg dm^{-3})	0.021 ± 0.005^{b}	0.026 ± 0.005^{b}	0.027 ± 0.006^{b}	0.038 ± 0.010^{b}	0.211 ± 0.048^{a}
NO_3 -N (mg dm^{-3})	0.187 ± 0.022^{b}	0.217 ± 0.028^{b}	0.272 ± 0.033^{b}	0.390 ± 0.056^{ab}	0.608 ± 0.096^{a}
Specific Conductivity (m mhos cm^{-1})	0.586 ± 0.051^{b}	0.612 ± 0.053^{b}	0.672 ± 0.065^{b}	0.786 ± 0.072^{b}	1.156 ± 0.146^{a}

* *for pH, the range of recorded values are presented*

On average, plankton volume was highest in the WE1 treatment followed in descending order by the WE2, WE3, WE4, and NE treatments ($P < 0.05$) (Table 2). The plankton volume primarily consisted of zooplankton. Phytoplankton accounted for 9.53% (WE1) to 46.08% (NE) of the total plankton content. The abundance (no. dm^{-3}) of the different plankton groups also differed considerably. The average number of cladocerans in WE1 (597.09) was 462% the average number of the same group in the NE treatment (129.17). The copepoda was most dominant among the zooplankton in all the treatments ranging from 47.65 % in WE1 to 53.91 % in NE (Table 2).

TABLE 2

Species composition, abundance (no. dm^{-3}), and relative abundance (% of total numbers) of plankton in culture tanks manured with poultry excreta under different water exchange regimes. Each mean value represents data from 25 samples collected two times a week during the three-month growth period

Species	Treatment									
	WE1		WE2		WE3		WE4		NE	
	(no. dm^{-3})	(%)	(no. dm^{-3})	(%)	(no. dm^{-3})	(%)	(no. dm^{-3})	(%)	(no. dm^{-3})	(%)
Chlorella sp.	30.12	2.01	29.12	2.06	26.24	2.14	40.16	4.43	52.12	8.14
Navicula sp.	38.24	2.55	42.12	2.98	40.76	3.33	43.71	4.82	56.11	8.76
Spirogyra sp.	25.12	1.67	23.06	1.63	31.12	2.54	51.16	5.64	68.24	10.66
Scenedesmus sp.	8.70	0.58	8.12	0.57	9.22	0.75	16.44	1.81	28.18	4.40
Phacus sp.	36.15	2.41	42.26	2.99	48.12	3.93	64.14	7.07	80.15	12.52
Synedra sp.	4.61	0.30	5.03	0.35	5.62	0.46	6.78	0.74	10.20	1.59
Total phytoplankton	142.94	9.53	149.71	10.59	161.08	13.17	222.39	24.52	295.00	46.08
Daphnia sp.	252.30	16.82	200.72	14.20	178.66	14.61	91.29	10.06	39.12	6.11
Moina sp.	276.24	18.41	258.22	18.27	194.52	15.91	128.24	14.14	66.05	10.32
Bosmina sp.	68.55	4.57	63.32	4.48	63.20	5.17	50.14	5.53	24.00	3.75
Cladocera	597.09	39.80	522.26	36.96	436.38	35.69	269.67	29.73	129.17	20.18
Cyclops sp.	324.05	21.60	368.24	26.06	272.14	22.26	184.62	20.36	95.12	14.86
Diaptomus sp.	252.44	16.83	205.12	14.52	196.02	16.03	126.55	13.95	60.28	9.42
Nauplii	70.12	4.67	66.24	4.69	66.16	5.41	44.28	4.88	22.14	3.46
Copepoda	646.61	43.10	639.60	45.27	534.32	43.70	355.45	39.19	177.54	27.73
Brachionus sp.	67.08	4.47	60.92	4.31	56.12	4.59	32.14	3.54	20.18	3.15
Keratella sp.	46.22	3.08	40.32	2.85	34.66	2.83	27.20	3.00	18.22	2.84
Rotifera	113.30	7.55	101.24	7.16	90.78	7.42	59.34	6.54	38.40	5.99
Total zooplankton	1357.00	90.47	1263.10	89.41	1061.48	86.83	684.46	75.48	345.11	53.92
Total plankton	1499.94		1412.81		1222.56		906.85		640.11	

The final body weight of the koi carp ranged from 3.01 to 9.56 g in the different treatments (Table 3). At harvest, maximum weight gain was achieved in the WE1 treatment, followed in descending order by the WE2, WE3, WE4, and NE treatments ($P < 0.05$). There was a direct correlation ($r = 0.986$; d.f.= 13; $P < 0.01$) between the weight gain of koi carp and the amount of plankton present in the five treatments (Fig. 1). All the data related to regressions of the natural log of average fish weight over time for each treatment fitted an exponential model with R^2 values of 0.729, 0.717, 0.739, 0.882, and 0.903 for the WE1, WE2, WE3, WE4, and NE treatments, respectively (Table 3).

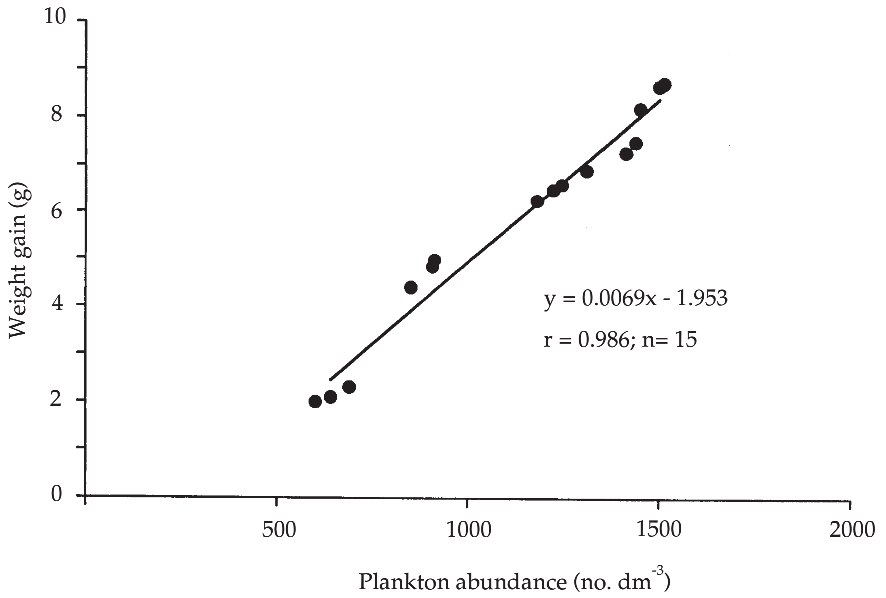

Fig. 1. Relationship between weight gain of koi carp and plankton abundance in the five treatments.

TABLE 3

Mean ± SE of fish growth parameters at the end of the three-month growth period (June - August, 2002) of koi carp reared in concrete tanks manured with poultry excreta under different water exchange regimes. Data in the same row with different superscripts are significantly different ($P < 0.05$)

	Treatment				
	WE1	WE2	WE3	WE4	NE
Initial body weight (g)	0.09 ± 0.02 ^{a}	0.09 ± 0.02 ^{a}	0.09 ± 0.02 ^{a}	0.09 ± 0.02 ^{a}	0.09 ± 0.02 ^{a}
Harvest weight (g)	9.56 ± 0.08 ^{a}	8.18 ± 0.08 ^{b}	7.39 ± 0.10 ^{b}	5.75 ± 0.08 ^{c}	3.01 ± 0.11 ^{d}
Weight gain (g)	9.47 ± 0.08 ^{a}	8.09 ± 0.08 ^{b}	7.30 ± 0.10 ^{b}	5.66 ± 0.08 ^{c}	2.91 ± 0.11 ^{d}
SGR (% day^{-1})	5.16 ± 0.05 ^{a}	5.08 ± 0.06 ^{b}	4.89 ± 0.12 ^{c}	4.61 ± 0.08 ^{d}	3.92 ± 0.03 ^{e}
Survival rate (%)	95.21 ± 1.03 ^{a}	89.61 ± 0.76 ^{b}	81.96 ± 0.89 ^{c}	74.84 ± 0.34 ^{d}	60.43 ± 2.39 ^{e}
Growth Equation*	$Y = e^{-1.56+0.320\,t}$ ($R^2 = 0.729$)	$Y = e^{-1.55+0.309\,t}$ ($R^2 = 0.717$)	$Y = e^{-1.65+0.306\,t}$ ($R^2 = 0.739$)	$Y = e^{-1.81+0.292\,t}$ ($R^2 = 0.882$)	$Y = e^{-2.04+0.262\,t}$ ($R^2 = 0.903$)

**The growth models predict weight of fish (Y = g fish) as a function of time (t = weeks)*

The Specific Growth Rate (SGR) was quite high (> 3.5) in all the treatments, although the differences among the various treatments were significant ($P < 0.05$). There was a significant difference ($P < 0.05$) in the survival of koi carp among the treatments, ranging from 60.43% (NE) to 95.21% (WE1). To determine the output of marketable fish, the percentage and number of fish exceeding a total weight of 4 g was estimated from the size-frequency distribution at the end of the study. The number of marketable fish was significantly higher in WE1 ($P < 0.05$), followed in descending order by the WE2, WE3, WE4, and NE treatments (Table 4).

TABLE 4

The average number of marketable fish (those heavier than 4.0 g) produced, together with marketable fish produced expressed as a percentage of total number of fish produced (A) and as a percentage of number of fish stocked (B) in the five treatments

Treatment	Number of marketable fish produced (fish tank^{-1}) *	Marketable fish (%)	
		A	B
WE1	380 ^{a}	100	95.21
WE2	358 ^{b}	100	89.61
WE3	327 ^{c}	100	81.75
WE4	300 ^{d}	100	74.90
NE	0.05 ^{e}	0.020	0.012

** Different superscripts in this column represent statistically significant differences ($P<0.05$)*

DISCUSSION

There was autochthonous production of plankton in all the treatments, following the principal of pond fertilization. As observed from the gut analysis of common carp (Chakrabarti and Jana 1991), zooplankton formed the main source of food. Water exchange rates had a direct influence on the water quality in the different treatments. The lack of water exchange in the NE treatment significantly lowered the dissolved oxygen ($P < 0.05$) and simultaneously increased specific conductivity, PO_4-P, NH_4-N, NO_2-N, NO_3-N, and BOD, compared to the other treatments (Table 1). According to Pechar (2000), the gradual accumulation of organic matter in a water body leads to the subsequent dominance of biodegradation and decomposition processes and causes an oxygen deficit. The resulting release of nutrients leads to excessive levels of autotrophic production, as well as changes in the species composition of plankton. Water quality deteriorates through the dynamic, multiple feedback process.

NH_4-N, incorporated from the application of organic manure as well as the metabolism of the water body, might be considered an index of environmental stress (Jana and Chakrabarti 1993). High concentrations of NH_4-N were found to restrict the occurrence of many small protozoans like ciliates that are considered as excellent food for cladocerans (Pfister et al. 2002). The presence of a relatively higher density of cladocerans in the WE1, WE2, WE3, and WE4 treatments, compared to NE, might be a consequence of a better environment in terms of water quality and food abundance. According to Herbert (1978), the maximum size reached by individuals of a particular species of Daphnia depends upon the food supply. Studies on life history parameters of *Daphnia* sp. (Jana and Pal 1983, Murugan 1989) and *Moina* sp. (Jana and Pal 1985) also suggest that growth, reproductive potential, and the longevity of each species are affected by the nutrient conditions of the culture media.

Perhaps the significantly high level of nutrients and BOD, along with low dissolved oxygen concentration in the NE treatment, lowered the grazing activity of the carp. The results clearly indicate that no water exchange in the NE treatment yielded the lowest number ($P < 0.05$) of saleable fish. In contrast to food fish production, where the total number of fish produced determines productivity, ornamental fish can only be sold once they have reached a particular size. The systematic discharge of water in WE1, WE2, WE3, and WE4 treatments significantly increased ($P < 0.05$) the number of marketable fish (Table 4). The greater dilution of the manure in these four treatments improved water quality (Table 1) and caused greater plankton abundance (Table 2) compared to the NE treatment, although the plankton volume within the four water exchange regimes differed significantly ($P < 0.05$). Differences in the relative abundance of some groups of zooplankton might have contributed to the differential growth responses and the survival of the carp. The unavailability or a non-continuous supply of preferred food have been reported to influence cannibalism in koi carp larvae (Appelbaum et al. 1986, Van Damme et al. 1989). Rothbard (1982) reported low survival rates in common carp as a result of severe competition for food when stocked at high densities. Interestingly, reduction in cannibalism in common carp was demonstrated by Von Lukowicz (1979), when a continuous supply of live food was maintained. Food availability is probably the most important factor determining the cannibalism rate in fish larvae (Hecht and Appelbaum 1988). As reported in this paper, the influence of plankton level on the growth heterogeneity and survival rate (Table 3) of koi carp larvae supports this last hypothesis.

The survival rate of koi carp was also influenced by water quality. Nitrite ions are toxic to fish, causing methaemoglobinemia (Tomasso et al. 1979). It is present in water as an intermediate in the bacterial oxidation of ammonia, the major nitrogenous waste product of fish, to nitrate (Das et al. 2004). An increase in the nitrite content in water exerts considerable stress on the fish resulting in growth suppression, tissue damage, and mortality (Lewis and Morris 1986) resulting in poor biomass production. Diminished respiration ability in nitrite-exposed grass carp, *Ctenopharyngodon idella* (Val.), was reported by Alcaraz and Espina (1997). Korwin-Kossakowski and Ostaszewska (2003) also reported the adverse impact nitrite exposure had on common carp respiration and growth. Allowable levels are therefore low; NO_2-N levels above 0.06 mg dm^{-3} have been observed to cause a minimal degree of harm in rainbow trout, *Oncorhynchus mykiss* (Walbaum), after three weeks of exposure (Wedemeyer and Yasutake 1978). The need to draw on such data arises from the relative absence of data on ornamental fishes. During the current experiment, koi carp larvae were exposed to an average NO_2-N concentration of 0.211 mg dm^{-3} in NE for three months, which was higher than the 0.06 mg dm^{-3} limit reported for rainbow trout. Compared to NO_2-N, NO_3-N is relatively harmless and can cause stress only at very high levels (Asano et al. 2003).

Unionized ammonia is also regarded as highly poisonous to fish (Arillo et al. 1981). The permeability of the uncharged and lipid soluble unionized ammonia (NH_3) to plasma membranes is higher compared with the ionized form, and therefore it is considered to be the more toxic form (Meade 1985). Earlier studies have shown that common carp are relatively sensitive to unionized ammonia with a reported LC_{50} value of 0.44-1.9 mg dm^{-3} (Dabrowska and Sikora 1986, Xu et al. 1994). Although unionized ammonia was not measured in the current experiment, it can be assumed that high temperature and pH levels during the entire growth period would block the ionizing process of NH_3 to the relatively non-toxic NH_4-N (Ng et al. 1992). In the current study, the average NH_4-N in NE was 0.753 mg dm^{-3}, when the average pH was 7.36 and the average temperature was above 30°C. Under these conditions, the percentage of NH_3 in the water was estimated to be about 2% of the NH_4-N (Emerson et al. 1975), *i.e.*, 0.015 mg dm^{-3}, which is below the threshold limit of 0.44 mg dm^{-3}. However, according to Parma de Croux and 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 NH_3 toxicity. Mortality might also arise due to depressions of feeding when water quality is sub-standard (Asano et al. 2003). These factors probably influenced the low survival rate (60.43%) of koi carp in the NE treatment.

The continuous supply of oxygen through aeration is known to promote nitrification in ponds, thereby lowering ammonia levels (Avnimelech et al. 1986). Since most farmers in India cannot afford aeration equipment, water exchange is used as an alternative to maintain water quality. However, high levels of water exchange could flush out nitrifying bacteria leading to reduced nitrification and increased ammonia concentrations (Diab et al. 1992, Milstein et al. 2001). Perhaps the solution lies in a low level of water exchange (only 5%, as in the present study) but with increased frequency. From the present investigation, a daily water exchange rate of 100 dm^3 (WE1) appeared to be the most effective for koi carp tanks manured with poultry excreta. No water exchange (NE) resulted in water quality deterioration, the depletion of the plankton population, and an adverse impact on fish growth.

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REFERENCES

Alcaraz G., Espina S. 1997 – Scope for growth of juvenile grass carp *Ctenopharyngodon idella* exposed to nitrite – Comp. Biochem. Physiol. 116 C: 85-88.

Anderson J.M., Ingram J.S.I. 1993 – Soil organic matter and organic carbon – In: Tropical Soil Biology and Fertility (Ed.) J.M. Anderson and J.S.I. Ingram, CAB International, Wallingford: 62-66.

APHA 1998 – Standard Methods for the Examination of Water and Waste Water – 20th Edition. American Public Health Association, Washington D.C.

Appelbaum S., Anderson P., Mochendorf C. 1986 – Cannibalism in reared koi carp larvae – In: Aquaculture of Cyprinids. (Ed.) R. Billard and J. Marcel, INRA, Paris: 235-239.

Arillo A., Margiocco C., Melodia F., Mensi P., Schenone G. 1981 – Ammonia toxicity mechanism in fish: Studies on rainbow trout *(Salmo gairdneri* Rich.) – Ecotoxicol. Environ. Saf. 5: 316-328.

Asano L., Ako H., Shimizu E., Tamaru C.S. 2003 – Limited water exchange production systems for freshwater ornamental fish – Aquacult. Res. 34: 937-941.

Avnimelech Y., Weber B., Hepher B., Milstein A., Zoran M. 1986 – Studies in circulated fish ponds: organic matter recycling and nitrogen transformations – Aquacult. Fish. Manage. 17: 231-242.

Boyd C.E. 1982 – Water Quality Management in Pond Fish Culture– Elsevier Scientific Publishing Company, Amsterdam.

Chakrabarti R., Jana B.B. 1990 – Food preferences and selection by common carp (*Cyprinus carpio*) fry under different feeding regimes – J. Appl. Ichthyol. 6: 223-230.

Chakrabarti R., Jana B.B. 1991 – Plankton intake as a function of body weight by common carp fry in different feeding conditions – Aquaculture 93: 21-34.

Chakrabarti R., Jana B.B. 1998 – Effects on growth and water quality of feeding exogenous plankton compared to use of manure in the culture of mrigal, *Cirrhinus mrigala,* and rohu, *Labeo rohita*, fry in tanks – J. Appl. Aquacult. 8: 87-95.

Dabrowska H., Sikora H. 1986 – Acute toxicity of ammonia to common carp (*Cyprinus carpio* L.) – Pol. Arch. Hydrobiol. 33:121-128.

Das P.C., Ayyappan S., Jena J.K., Das B.K. 2004 – Nitrite toxicity in *Cirrhinus mrigala* (Ham.): acute toxicity and sublethal effect on selected haematological parameters – Aquaculture 235: 633-644.

Diab S., Kochba M., Mires D., Avnimelech Y. 1992 – Combined intensive - extensive (CIE) pond system. A: Inorganic nitrogen transformations – Aquaculture 101: 33-39.

Emerson K., Russo R.C., Lund R.E., Thurston R.V. 1975 – Aqueous ammonia equilibrium calculations: effect of pH and temperature – J. Fish. Res. Bd. Can. 32: 2379-2383.

Fernando A.A., Phang V.P.E. 1985 – Culture of the guppy, *Poecilia reticulata* in Singapore – Aquaculture 51: 49-63.

Francis-Floyd R. 1990– Stress - its role in fish diseases – IFAS Circular 919, Florida Cooperative Extension Service, University of Florida, Gainesville.

Green B.B., Phelps R.P., Alvarenga H.R. 1989 – The effect of manures and chemical fertilizers on the production of *Oreochromis niloticus* in earthen ponds – Aquaculture 76: 37-42.

Hecht T., Appelbaum S. 1988 – Observation on intraspecific aggression and coeval sibling cannibalism by larval and juvenile *Clarias gariepinus* (Claridae: Pisces) under controlled conditions – J. Zool. Soc. (London) 214: 21-44.

Hepher B. 1962 – Primary production in fish ponds and application to fertilization experiment – Limnol. Oceanogr. 7: 135-136.

Herbert P.D.N. 1978 – The population biology of *Daphnia* (Crustacea, Daphnidae) – Biol. Rev. 53: 387-426.

Jana B.B., Pal G.P. 1983 – Some life history parameters and production of *Daphnia carinata* (King) under different culturing media – Water Res. 17: 735-741.

Jana B.B., Pal G.P. 1985 – The life history parameters of *Moina micrura* (Kurz.) grown in different culturing media – Water Res. 19: 863-868.

Jana B.B., Chakrabarti R. 1993 – Life table responses of zooplankton *(Moina micrura* Kurz and *Daphnia carinata* King) to manure application in a culture system – Aquaculture 117: 274-285.

Jha P., Sarkar K., Barat S. 2004 – Effect of different application rates of cowdung and poultry excreta on water quality and growth of ornamental carp, *Cyprinus carpio* vr. *Koi,* in concrete tanks – Turk. J. Fish. Aquat. Sci. 4: 17-22.

Knud-Hansen C.F., Batterson T.R. 1994 – Effects of fertilization frequency on the production of Nile tilapia (*Oreochromis niloticus*) – Aquaculture 123: 271-280.

Korwin-Kossakowski M., Ostaszewska T. 2003 – Histopathological changes in juvenile carp *Cyprinus carpio* L. continuously exposed to high nitrite levels from hatching – Arch. Pol. Fish. 11: 57-67.

Lewis Jr. W.M., Morris D.P. 1986 – Toxicity of nitrite to fish: a review – Trans. Am. Fish. Soc. 115: 183-195.

Meade W.J. 1985 – Allowable ammonia for fish culture – Prog. Fish-Cult. 47: 135-145.

Milstein A., Avnimelech Y., Zoran M., Joseph D. 2001 – Growth performance of hybrid bass and hybrid tilapia in conventional and active suspension intensive ponds – Isr. J. Aquacult. / Bamidgeh 53: 147-157.

Moore L.B. 1985 – The role of feeds and feeding in aquatic animal production – Geojournal 10: 245-251.

Murugan N. 1989 – The mass culture of a cladoceran, *Daphnia carinata* (King), for use as food in aquaculture – In: Aquacultural Research in Asia: Management Techniques and Nutrition (Ed.) E.A. Huisman, N. Zonneveld and A.H.M. Bouwmans, Pudoc, Wageningen: 190-202.

Ng W.J., Kho K., Ho L.M., Ong S.L., Sim T.S., Tay S.H., Goh C.C., Cheong L. 1992 – Water quality within a recirculating system for tropical ornamental fish culture – Aquaculture 103: 123-134.

Parma de Croux M.J., Loteste A. 2004 – Lethal effects of elevated pH and ammonia on juveniles of neotropical fish *Colosoma macropomum* (Pisces, Caracidae) – J. Environ. Biol. 25: 7-10.

Pechar L. 2000 – Impacts of long-term changes in fishery management on the trophic level water quality in Czech fish ponds – Fish. Manage. Ecol. 7: 23-31.

Pfister G., Auer B., Arndt H. 2002 – Pelagic ciliates (Protozoa, Ciliophora) of different brakish and freshwater lakes - a community analysis at the species level – Limnologica 32: 147-168.

Ricker W.E. 1975 – Computation and interpretation of biological statistics of fish populations – Bull. Fish. Res. Bd. Can. 191: 1-382.

Rothbard S. 1982 – Induced reproduction in cultivated cyprinids - the common carp and the group of chinese carps: II. The rearing of larvae and primary nursing of fry – Bamidgeh 34: 20-32.

Schroeder G.L., Wohlfarth G., Alkon A., Halevy H., Krueger H. 1990 – The dominance of algal - based food webs in fish ponds receiving chemical fertilizers plus organic manures – Aquaculture 86: 219-229.

Sokal, R.R., Rohlf J.R. 1969 – Biometry – The Principles and Practice of Statistics in Biological Research- H.F. Freeman and Co., San Francisco.

SundarRao P.S.S., Richard J. 1999 – An Introduction to Biostatistics. 3rd Edition – Prentice Hall of India Pvt. Ltd., New Delhi.

Swain S.K., Jena J.K. 2002 – Ornamental fish farming. A new dimension in aquaculture entrepreneurship – In : Ornamental Fish Breeding and Culture for Entrepreneurship Development (Ed.) S.K. Swain, CIFA, Bhubaneshwar: 1-6.

Tomasso J.T., Simco B.A., Davis K.B. 1979 – Chloride inhibition of nitrite induced methemoglobinemia in channel catfish *(Ictalurus punctatus*) – J. Fish. Res. Bd. Can. 36: 1141-1144.

Van Damme P., Appelbaum S., Hecht T. 1989 – Sibling cannibalism of koi carp *Cyprinus carpio* L. larvae and juveniles reared under controlled conditions – J. Fish Biol. 34: 855-863.

Von Lukowicz M. 1979 – Experiments on first feeding of carp with Alevon and freeze - dried fish – EIFAC Tech. Pap. No. 35 (Suppl. 1): 94-102.

Walkley A., Black I.A. 1934 – An examination of the Degtjareff method for determining soil organic matter and prepared modifications of the chromic acid titration method – Soil Sci. 34: 29-38.

Wedemeyer G.A., Yasutake W.T. 1978 – Prevention and treatment of nitrite toxicity in juvenile steel head trout *(Salmo gairdneri*) – J. Fish. Res. Bd. Can. 35: 822-827.

Xu J., Ma X., Hou W., Han X. 1994 – Effects of temperature and ammonia on silver carp, bighead carp, grass carp and common carp – China Environ. Sci. 14: 214-218.

Zar J.H. 1996 – Biostatistical Analysis – Prentice Hall, Upper Saddle River, New Jersey.

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STRESZCZENIE

WPŁYW CZĘSTOTLIWOŚCI WYMIANY WODY NA JEJ JAKOŚĆ I PRODUKCJĘ KARPIA KOI (*CYPRINUS CARPIO* VAR. *KOI* L.) W BASENACH BETONOWYCH NAWOŻONYCH ORGANICZNIE

Określono wpływ częstotliwości wymiany wody na jej jakość oraz zasobność planktonu i produkcję karpia koi, *Cyprinus carpio* var. *koi* L. w betonowych basenach podchowowych, nawożonych kurzym obornikiem. Porównano indywidualne tempo wzrostu i przeżywalność ryb (masa początkowa 0,09 ± 0,02 g) w czterech wariantach doświadczalnych, w których woda o objętości 100 dm^3 była wymieniana: (1) codziennie (grupa WE1), (2) co drugi dzień (grupa WE2), (3) dwa razy w tygodniu (grupa WE3), (4) raz na tydzień (grupa WE4) – grupa kontrolna (NE) bez wymiany wody. W grupie kontrolnej (NE) stwierdzono istotnie wyższy ($P < 0,05$) poziom następujących wskaźników jakości wody: NH_4-N, NO_2-N, NO_3-N, PO_4-P, konduktywności, zasadowości węglanowej. Zagęszczenie planktonu było najwyższe w grupie WE1 ($P < 0.05$). Przyrost biomasy ryb również był istotnie wyższy w grupie WE1 ($P < 0,05$). Przeżywalność ryb w poszczególnych grupach była istotnie zróżnicowana i wahała się od 60,43% (grupa NE) do 95,21% (grupa WE1). Wyniki badań wskazują, że w podchowie karpia koi w basenach betonowych, nawożonych organicznie, zarówno ze względu na utrzymanie odpowiedniej jakości wody, jak i zagęszczenia planktonu najbardziej efektywna była wymiana 100 dm^3 wody dziennie (grupa WE1).