AgroLife Scientific Journal - Volume 9, Number 1, 2020
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

MANAGEMENT INDUCED CHANGES IN POND WATER QUALITY AND GROWTH PERFORMANCE OF GOLDFISH, *Carassius auratus* (L.), IN TWO 11-WEEK GROWTH EXPERIMENTS CONDUCTED DURING THE SUMMER AND WINTER SEASONS

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Abstract

To assess the seasonal influence on the growth performance of goldfish, Carassius auratus (L.) in earthen ponds maintained under different production management regimes, two 11-week growth experiments were conducted during two different seasons (summer and winter) under tropical conditions in India. Weight gain, survival rate and fish deformities were compared among four management regimes in each season: (1) fish larvae fed with live zooplankton (LF); (2) direct fertilization with poultry manure (PM); (3) direct fertilization with cow dung (CD); (4) a control system (C), where a commercial diet containing 32% crude protein was applied. The LF treatment produced significantly higher weight gain and survival rate of goldfish ($P < 0.05$) in both the trials through maintenance of better water quality and greater abundance of zooplankton in the system. Fish deformities were highest in the C treatment in both the experiments. Water temperature averaged 27.5°C and 16.2°C, respectively, in the summer and the winter trials. Average weight gain and survival rates of goldfish achieved during the winter trial were considerably lower than the summer trial ($P < 0.05$).

***Key words**: aquaculture management, fish production, goldfish, seasonal effect, water quality.*

INTRODUCTION

The bulk of ornamental fishes in the international aquarium trade is of freshwater origin and is farm-raised (Livengood and Chapman, 2007). The goldfish, *Carassius auratus* (L.), is a very popular ornamental fish and has a market for individuals as small as 4 g (minimum), that typically requires only about ten weeks of growth to attain the saleable size (Jha et al., 2006a; Jha, 2017). One of the critical bottlenecks that culturists have to face is the survival of the larvae that has just made the transition from an endogenous to an exogenous feeding habit in nursery tank conditions. Now, the same larvae, which have grown to about two weeks, are stocked under intensive culture conditions for quick growth in short period. Therefore, the level of expertise required in production management, particularly with relation to water quality is higher with ornamental fish than any other type of aquaculture (Watson and Shireman, 1996).

The fish are subjected to different kinds of aquaculture management that varies from farm to farm. The use of organic manures in ornamental fish production has been documented (Jha et al., 2004; Jha and Barat, 2005a). However, using organic manure can result in negative environmental impact (Jha, 2007) and supply of exogenous live food can be an effective alternative (Jha and Barat, 2005b; Jha et al., 2006b; 2008; Jha, 2019). Fish are unable to perform de novo synthesis of carotenoids (Goodwin, 1984) and rely on costly dietary supply to achieve their natural pigmentation (Paripatananont et al., 1999), since the market value of ornamental fish increases with intensity of skin colouration (Nica et al., 2019). Since Indian farmers are generally unable to provide costly dietary supplements, they stress on the supply of live food instead. Taking advantage of the tropical climate, fish culturists in India have the opportunity to harvest multiple crops throughout the year (Jha et al., 2007) where pond water temperature falls below 20°C for only three months in a year, i.e. mid-November to mid-February.

In the present experiment, two 11-week growth trials were conducted during two different seasons (summer and winter) to assess the seasonal influence on the growth performance of goldfish, *Carassius auratus* (L.) larvae in earthen ponds maintained under different production management regimes. The study also aimed to explore the possibility of use of exogenous plankton in promoting higher survival and growth of goldfish, compared to the traditional application of organic manure.

MATERIALS AND METHODS

Among the four prominent seasons distinguished throughout a year, we selected the summer and winter, for the two 11-week growth experiments: (1) 14 December' 12 – 01 March' 13 (winter); and (2) 14 April' 13 – 29 June' 13 (summer). Each seasonal trial was conducted in twelve outdoor earthen ponds (9.14 x 6.10 x 1.07 m; capacity: 59650 l each) in an ornamental fish farm (Rainbow ornamentals) in Jalpaiguri, India. Fish were cultured for 11 weeks according to one of the four treatments: (1) introduction of live zooplankton (live-food system or LF); (2) direct fertilization with poultry manure (PM); (3) direct fertilization with cow dung (CD); and (4) introduction of a commercial pelleted food (Tokyu Corp., Japan) into the ponds (control system or C). Three similar ponds were randomly assigned for each treatment.

About two weeks old goldfish larvae with an average initial weight of 0.10 ± 0.013 g (winter) and 0.12 ± 0.009 g (summer) were used in the growth experiments (n = 250 in each case). The larvae were stocked at 0.3 fish/l density, as optimized in an earlier experiment with koi carp, *Cyprinus carpio* L. (Jha and Barat, 2005c). The fish in the LF ponds were fed by transferring about 1000 l of plankton-rich water at a fixed hour (7 A.M.) every day in each pond from a series of plankton culture ponds that were fertilized with poultry manure and maintained under similar management conditions as the PM treatment. The entire experimental unit was covered by a single layer of bird netting. Constant water levels were maintained in the culture ponds by supplying ground water periodically to compensate for loss due to evaporation. Approximately 1000 l of excess water was discharged from each pond every day during the introduction of live plankton water.

The commercial diet applied in the control treatment was selected on the basis of widespread availability and contained 32% crude protein, 4% crude fat, 5% crude fibre, 10% crude ash, 9% moisture and 31% nitrogen free extract. The food was applied at 5% body weight of stocked fish once daily. The poultry and cow manures were collected from local farms, and allowed to decompose for 10 days prior to application. They were applied at a dose of 0.26 kg/m^3, every 10 days, in the PM and CD treatments, as standardized in an earlier experiment (Jha et al., 2004).

Samples of water were collected from each pond at a fixed hour of the day (9 A.M.) every week and were analyzed for various water quality parameters according to methods described in APHA (1998). Plankton samples were collected from all the ponds at about 5 hours after the introduction of plankton-rich water in the LF ponds with a plankton net made of standard bolting silk cloth (with 77 mesh/cm^2) two times 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 a Sedgwick Rafter Counting Cell.

Fish were harvested after 11 weeks of each trial. 250 fish were randomly selected from each treatment and weighed individually to the nearest 0.01 g. For this the fish were anaesthetized with tricaine methane sulphonate (MS – 222) of 0.04 g/l concentration. The Specific Growth Rate (SGR) 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 fish (g), respectively, and (t) is the culture period in days (Ricker, 1975). The number of fish with body deformities was also recorded during harvest. 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 percent mortality in each treatment. Final survival and deformities percentage were normalized using the arc sin angular transformation method (Mosteller and Youtz, 1961) before being subjected to further statistical analysis.

The results were statistically evaluated. Data on fish growth, survival and deformities in each seasonal trial was pooled for one way analysis of variance (ANOVA), and further subjected to Tukey's Test (Zar, 1999) to determine significant differences between the means. Statistical significance was accepted at $P < 0.05$ levels.

RESULTS AND DISCUSSIONS

Pond water temperature averaged 27.5ºC in summer and 16.2ºC in the winter trial. The variations of water temperature in the winter and summer growth experiments are shown in Figure 1. The results of the various water quality parameters in the experimental tanks during the different growth experiments are presented in Table 1. Values of dissolved oxygen (DO) and pH were significantly higher in LF and C ($P < 0.05$) than the manured treatments in both the seasonal experiments (Table 1).

Values of free CO_2, BOD, total alkalinity, phosphate, ammonium and nitrate were significantly higher ($P < 0.05$) in the manured treatments (PM and CD), compared to LF and C in both the experiments (Table 1). On an average, the plankton volume was highest in the PM treatment followed in decreasing order by the CD, LF and C treatments in both the experiments. However, the cladoceran population was highest in the LF treatment in both the cases (Figure 2).

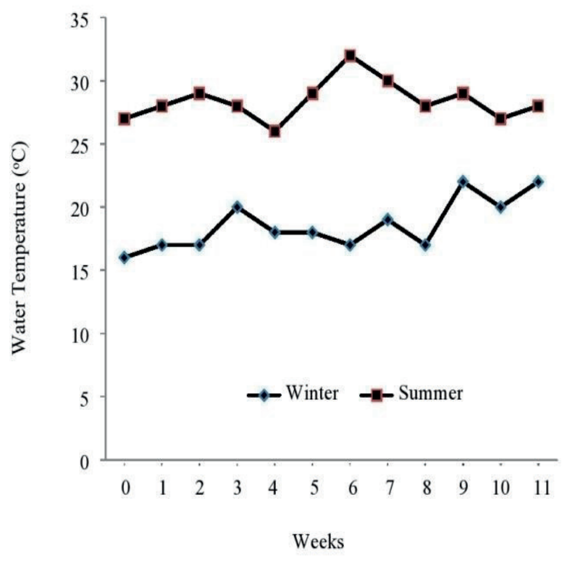

Figure 1. Weekly mean water temperature (ºC) recorded from the 12 fish culture ponds at 09.00 AM during the winter and summer growth experiments

In both the experiments, the average harvest weight of goldfish was highest ($P < 0.05$) in the LF treatment, followed in decreasing order by the PM, CD and C treatments (Table 2). Highest survival rates were obtained in the LF treatment ($P < 0.05$). The control treatment produced the highest number of deformed goldfish, while the lowest numbers were recorded in the LF treatment ($P < 0.05$). The average weight gain and survival rate of carp was lower during the winter growth trial in all the treatments, compared to the summer trial (Table 2).

In both the seasonal experiments, supply of exogenous plankton (LF) substantially improved weight gain ($P < 0.05$) and fish survival ($P < 0.05$), compared to the manured treatments (PM and CD) and control (C). Organic manures, if not decomposed completely before application in aquaculture pond may result in water quality degradation as they utilize oxygen during decomposition.

Therefore, the amount of any organic manure to be added in the pond mainly depends upon its biological oxygen demand, as their use may cause severe dissolved oxygen depletion in the pond and result in production of toxic gases, besides contributing to diseases (Chakrabarty et al., 2008).

Although the manures were allowed to decompose for 10 days prior to application in both the seasonal experiments, it could be possible that they were not properly decomposed and resulted in reduced water quality in the manured treatments.

Since the LF treatment received only the plankton rich water from the plankton culture ponds (maintained very similar to the PM treatment), it may well be that the toxic metabolites that were not assimilated by the phytoplankton and were the cause of water quality depletion in the manured ponds were severely diluted in the LF treatment and caused less damage.

Even the zooplankton abundance (no./l) was greater in LF, compared to PM and CD in both the seasonal experiments.

Table 1. Mean water quality parameters (SE in parentheses) in the four treatments recorded in the two growth trials during different seasons (winter and summer)

Culture period	Dissolved oxygen (mg/l)				pH (mg/l)			
	LF	PM	CD	C	LF	PM	CD	C
Winter	6.28^{a}	5.81^{b}	5.30^{c}	6.12^{ab}	7.25^{a}	6.26^{bc}	5.98^{c}	7.03^{ab}
	(0.20)	(0.25)	(0.15)	(0.10)	(0.12)	(0.23)	(0.15)	(0.15)
Summer	7.13^{a}	6.16^{c}	5.57^{d}	6.58^{b}	7.45^{a}	6.49^{b}	6.34^{b}	7.16^{ab}
	(0.29)	(0.20)	(0.21)	(0.19)	(0.18)	(0.22)	(0.28)	(0.20)
	Free CO_2 (mg/l)				BOD (mg/l)			
	LF	PM	CD	C	LF	PM	CD	C
Winter	2.21^{d}	3.32^{ab}	3.84^{a}	2.77^{bc}	0.91^{bc}	2.81^{a}	2.75^{a}	1.31^{b}
	(0.15)	(0.24)	(0.21)	(0.12)	(0.12)	(0.21)	(0.26)	(0.11)
Summer	1.42^{c}	2.49^{b}	3.17^{a}	2.19^{b}	0.78^{b}	1.96^{a}	1.90^{a}	1.01^{b}
	(0.12)	(0.15)	(0.22)	(0.20)	(0.07)	(0.30)	(0.18)	(0.11)
	NH_4-N (mg/l)				Alkalinity (mg/l)			
	LF	PM	CD	C	LF	PM	CD	C
Winter	0.09^{b}	0.34^{a}	0.38^{a}	0.13^{b}	35.70^{bc}	75.55^{a}	70.48^{a}	50.26^{b}
	(0.02)	(0.04)	(0.04)	(0.02)	(3.28)	(7.19)	(6.68)	(4.14)
Summer	0.10^{b}	0.28^{a}	0.30^{a}	0.12^{b}	31.26^{b}	70.85^{a}	65.55^{a}	38.25^{b}
	(0.01)	(0.03)	(0.04)	(0.02)	(2.86)	(6.66)	(6.14)	(5.36)
	NO_3-N (mg/l)				PO_4-P (mg/l)			
	LF	PM	CD	C	LF	PM	CD	C
Winter	0.05^{b}	0.29^{a}	0.24^{a}	0.08^{b}	0.12^{c}	0.62^{a}	0.55^{a}	0.26^{b}
	(0.01)	(0.03)	(0.02)	(0.01)	(0.01)	(0.08)	(0.04)	(0.02)
Summer	0.06^{b}	0.20^{a}	0.18^{a}	0.07^{b}	0.18^{b}	0.40^{a}	0.45^{a}	0.22^{b}
	(0.01)	(0.03)	(0.03)	(0.01)	(0.02)	(0.05)	(0.06)	(0.02)

Each mean value represents 12 samples collected at weekly intervals during each of the four 11-week seasonal trials. Different superscripts of each water quality parameter in the same row indicate statistically significant differences between means at 5% level. The treatments correspond to earthen ponds treated with live-food (LF), poultry manure (PM), cow dung (CD), and control (C)

Table 2. Summary of growth, SGR, deformities and survival rate of goldfish, *Carassius auratus* (L.), produced in the two growth experiments during different seasons (winter and summer)

	Treatment			
	LF	PM	CD	C
Harvest weight (g ± SE)				
Winter	4.35 ± 0.21^{a}	3.87 ± 0.11^{b}	3.56 ± 0.11^{bc}	2.25 ± 0.09^{d}
Summer	7.62 ± 0.27^{a}	5.23 ± 0.15^{b}	4.32 ± 0.14^{c}	3.50 ± 0.08^{d}
Weight gain (g ± SE)				
Winter	4.25 ± 0.21^{a}	3.77 ± 0.11^{b}	3.46 ± 0.11^{bc}	2.15 ± 0.09^{d}
Summer	7.50 ± 0.27^{a}	5.11 ± 0.15^{b}	4.20 ± 0.14^{c}	3.38 ± 0.08^{d}
SGR (%/ day)				
Winter	4.83 ± 0.21^{a}	4.68 ± 0.11^{b}	4.58 ± 0.11^{c}	3.99 ± 0.09^{d}
Summer	5.32 ± 0.27^{a}	4.83 ± 0.15^{b}	4.59 ± 0.14^{c}	4.32 ± 0.08^{d}
Deformed individuals (%)				
Winter	2.8^{d}	5.7^{c}	9.1^{b}	18.1^{a}
Summer	0.9^{d}	3.9^{c}	5.6^{b}	12.5^{a}
Survival rate (%)				
Winter	90.1^{a}	79.2^{b}	70.2^{c}	67.5^{c}
Summer	96.3^{a}	88.9^{b}	80.5^{c}	74.4^{d}

Each mean value (apart from survival rate) represents 250 randomly selected samples during harvest. Different superscripts in the same row indicate statistically differences between means at 5% level. Treatments represent earthen ponds treated with live-food (LF), poultry manure (PM), cow dung (CD), and control (C)

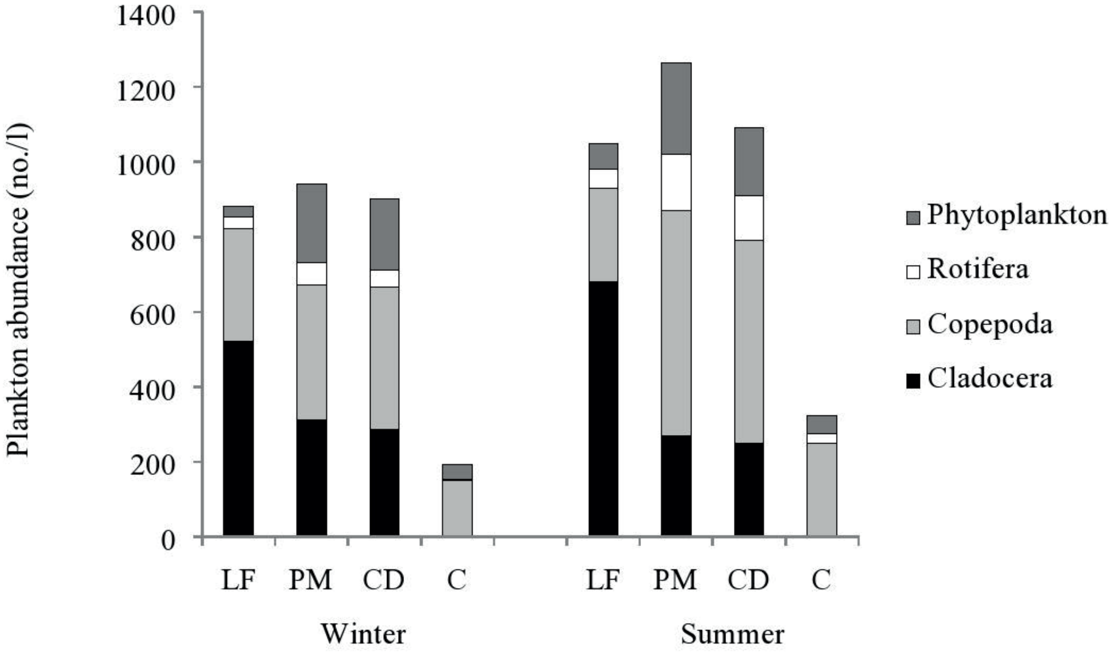

Figure 2. Plankton abundance (no./l) in the four treatments during the winter and summer growth experiments

Cladocerans are easily digestible due to the presence of digestive enzymes (Kumar et al., 2005) and they have high energetic caloric value (Morris and Mischke, 1999). The life history parameters of several cladocerans (Jana and Pal, 1985; Urabe and Watanabe, 1992) suggest a definitive role of the culture media in their growth and reproduction. Maximum concentration of cladocerans in the LF treatment could be a consequence of improved water quality and is in agreement with earlier findings (Jha and Barat, 2005b; Jha et al., 2006a; 2006b; 2008).

The zooplankton concentration in any particular treatment was higher in the summer experiment, compared to winter (Figure 2).

The phytoplankton and zooplankton communities, which develop in rearing ponds, are influenced by interactions between temperature, photoperiod, water quality, nutrient availability and fish predation (Geiger, 1983). The egg production and hatching rate of zooplankton are normally lower at low temperature, and generally increase with increasing temperature up to a thermal threshold (Santhanam et al., 2013). Similar trend has been reported by Longoria (2003), Rhyne et al. (2009), and Santhanam and Perumal (2012). On the other hand, Dodson (1974) had suggested that in summer, planktonic individuals have a reproductive disadvantage because of energetic costs associated with the development of the antipredator structures. Some researchers have shown that the chemicals released by invertebrate predators may induce the defensive morphologies, reduce growth rate, brood size, and survival rate of certain zooplankton (Havel and Dodson, 1987; Ketola and Vuorinen, 1989). However, in properly maintained aquaculture ponds as employed in the present experiments, there was reduced risk of invertebrate predator infestation and the zooplankton were primarily consumed by the cultured fish that was similar in both the seasonal trials. Lower weight gain of goldfish during the winter trial in our experiment may also be related to the lower abundance (no./l) of zooplankton in winter (Figure 2). Similar decrease in zooplankton abundance during winter was been reported by Dhawan and Kaur (2002), and Jha et al. (2006b).

Temperature is one of the most important factors determining somatic growth of fish (Hofmann and Fischer, 2003). The goldfish are known to tolerate extreme and fluctuating temperatures (Reynolds and Casterlin, 1979; Ford and Beitinger, 2005). Growth performance in a related species, the crucian carp (*Carassius carassius*) is also known to be influenced by temperature (Holopainen et al., 1997; Coop et al., 2010). For any fish species, there is no fixed temperature preference as such. Rather, in a large waterbody, a fish does not move to water of a given temperature within a gradient and then remain there, but tends to make 'exploratory movements' into waters of both lower and higher temperature (Jobling, 1981). Therefore, it may be more realistic to consider a temperature range rather than a fixed temperature. In our experiment, average water temperature during the winter growth experiment (range: 16°C-22°C; n = 12) was 11.3°C lower than the summer average (range: 26°C-32°C; n = 12). It appears that the temperature range of 26°C-32°C suited better growth and survival of goldfish, compared to lower temperatures. Survival rates of goldfish ranged from 68.5% (C) to 90.1% (LF) in the winter trial, and were lower by 6.2% to 10.3% in the different treatments, compared with the summer trial (Table 2). In our experiment, weight gain of goldfish in all the treatments was much lower in winter, compared with the summer growth experiment (Table 2). The results correspond to an earlier experiment with koi carp where an 83.8% increase in weight gain was achieved during the summer, compared with a winter growth experiment (Jha et al., 2007). According to Horvath et al. (1992), metabolism and food demand of carp decreases gradually with decreasing water temperatures below 20°C, leading to lower growth rates. Information relating to the growth of estuary grouper, *Epinephelus salmoides* from the experimental cage sites showed that the annual temperature conditions (28-32°C) were close to those promoting maximum growth (Chua and Teng, 1980; Jobling, 1981).

Significantly higher ($P < 0.05$) incidences of fish deformities were obtained in the control treatment in both the seasonal experiments. This could be attributed to nutritional deficiencies caused by lower abundance of plankton and possible leaching of nutrients out of the pelleted food (Jha, 2007; 2010; Myszkowski et al., 2002). In ornamental high-value species such as goldfish (*Carassius auratus*), emphasis should be given to achieving high levels of skin pigmentation, body shape, fin shape and body size, that are the most important quality criteria informing their market value (Paripatananont et al., 1999). The percentage of fish deformities were higher in the winter trial, compared to summer.

CONCLUSIONS

From the present investigation, the winter season appeared to be less productive for goldfish culture, compared to summer. In both the seasonal experiments, the live-food treatment (LF) appeared to be the most effective for goldfish culture compared to poultry manure (PM) or cow dung (CD) treatments, through maintenance of better water quality and greater abundance of zooplankton in the system.

ACKNOWLEDGEMENTS

The author is grateful to Manabendra Nath Moitra and Late Ramkanta Ray of P.D. Women's College, Jalpaiguri, India for their assistance in conducting in some of the water- quality experiments. Kripan Sarkar, the owner of the Rainbow Ornamental Fish Farm, Jalpaiguri, India, provided the fish and experimental support.

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