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Polyhouse driven raised-temperature induces cichlid tilapia to breed during winter

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ABSTRACT

Two experiments were performed to examine the impact of global warming on the growth of some carps, and growth and breeding performance of tilapia in small holding tanks using polyhouse model for testing the green house driven raised-temperature on breeding performance of tilapia during winter months. Advanced fry of fish (rohu, bata, paku and common carp) as well as semi-adult male (2) and female (2) tilapia were reared for 91 or 98 days. The net weight gain of tilapia did not differ between outside and inside the polyhouse. Growth differences in rest of the fishes tested were not significant between enclosed and outside polyhouse. Tilapia held in enclosed polyhouse tanks bred and produced fry with numbers ranging from 28 - 36 / tank, whereas, there was no trace of breeding in tanks placed outside the polyhouse with ambient temperature. Water temperature remained to be significantly higher in the enclosed polyhouse compared to outside tanks. Raised water temperature of around 2.93°C inside the polyhouse over the ambient temperature outside was responsible for breeding activities of multiple spawner cichlid tilapia *Oreochromis mossambicus*. However, water quality parameters did not differ between the enclosed and outside polyhouse. It may be concluded that the benefit of closed polyhouse may be profitably used by the fish farmer for inducing breeding in tilapia and growth enhancement in other Indian fishes during winter months and colder region of the country in general.

Key words: Cichlid fishes, Climate change, Polyhouse, Polyhouse driven raised temperature, Tilapia breeding

Wetlands rich in microalgae, aquatic vegetation and a habitat for vast array of fish cover 6% of the world's land surface, contain about 12% of the global carbon pool and, hence play an important role in the global cycling of carbon (IPCC 2000, Ferrati *et al.* 2005). Considerable efforts have been made to quantify carbon sequestration in many inland water bodies (Dean and Gorham 1998) as well as land soils (Lal 2004). The importance of aquaculture ponds in global carbon sequestration is immense considering their 110,830 km^2 distribution worldwide (Verdgem and Bosma 2009) and its utilization as carbon reduction credits against carbon emissions from aquaculture production (Boyd *et al.* 2010).

Since the fishes are poikilothermous, any change in water temperatures would alter the food consumption, growth, reproduction and physiological cellular functions of fish. de Graaf (1999) reported that oocyte development rather than gonado-somatic index of Nile tilapia (*Oreochromis niloticus*) is a better indicator of maturation. For tilapia breeding, the lethal extreme temperature should be between 24° and 30°C (Murnyak 2010).

It is hypothesized that polyhouse simulated for green house effects would raise water temperature that may be profitably used to induce tilapia to breed during winter months in tropical areas when no spawning activities are noticed under natural conditions without environmental manipulations. However, hardly is known about the impact of climate change on growth and breeding performance of fish especially using multiple spawner cichlid fish as model.

The purpose of the study was to examine the impact of global warming under simulated green house condition (polyhouse) on the breeding potentials of tilapia and growth of some Indian carps in small holding tanks so as to harvest the benefit of global warming during winter for providing low cost fish protein to the poor using small holding tanks along with economic development of large populations of villagers having no access of their own aquaculture ponds.

MATERIALS AND METHODS

Two experiments were performed during September to December (2011) as well as during December 2011 through March 2012. The first experiment was conducted in 6 outdoor tanks (300 l capacity) and the second trial used fifteen outdoor tanks for examining the growth of some

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Indian carps (rohu, bata, paku, tilapia and common carp) as well as growth and breeding of tilapia under polyculture (Table 1).

Out of 21 tanks used, 15 (12 in first and 3 in second experiment) tanks were placed inside the polyhouse and 6 tanks (3 in each experiment) outside the polyhouse and served as negative control. The polyhouse was constructed with conventional bamboo structure and covered by standard transparent polythene so as to mimic as green house generating raised temperature according to the principle of green house emission of gases. The tanks were provided with 18 cm alluvial soil at the bottom and filled with aerated ground water (pH - 7.2). The experimental conditions for the second trial were the same as that of first one except that the water used was collected from different local fish ponds having different pH conditions (pH- 7, 8 and 9) coupled with different CO_2-CO_3- HCO_3 system as well as a mixed pH condition created by mixing equal volume of three different pond water. Thus, different initial pH conditions of water were used in the second trial: 7. 8, 9 and their mix. After few days of settlement, the tanks were added with cattle manure (25 g/tank) and NPK fertilizer (19%) (10 g/tank) every 10 days for adequate algal production.

Advanced fry of different species of test fish (rohu - 5.8 g, bata - 2.6 g, tilapia - 9.0 g, paku - 2.2 g) were procured from local sources, well acclimatized and introduced into the tank @ 12 nos/tank (rohu- 3, bata -2, tilapia- 4 and paku - 3) 10 days after application of fertilizers when the colour of water changed to greenish blue indicating the development of adequate plankton and reared for 91 or 98 days.

The next trial examined the growth performance of different species of fish (tilapia 15.48 g - 4, rohu 7.58 g - 2, bata 1.55 g - 3 and common carp 1.85 g - 2) under different initial pH conditions coupled with different CO_2-CO_3-HCO_3 system during the winter (December through March). Both male (2) and female (2) semi- adult tilapia were introduced into each tank. Supplementary feeding using standard fish meal was provided every day. After 91 or 98 days of rearing, all the fishes were harvested in January or March. The body weight of each fish harvested was recorded; the number of fry produced / tank was also counted. The fry produced / tank was also weighed and grouped accordingly.

Important water quality parameters (temperature, pH, free carbon dioxide, ammonium-N, nitrite-N and nitrate-N, phosphate and primary productivity of phytoplankton) were monitored from all the tanks at periodical intervals following the standard protocols (APHA 2005).

Procured data on different water quality parameters at close intervals from different tanks maintained in the enclosed and outside polyhouse were subjected frequency analysis using a distinct class intervals of the parameter in the abscica. Also the data were statistically evaluated; t-test was applied to find the differences in mean values of different parameters (water temperature, pH, fish growth) between the enclosed and outside the polyhouse tanks. Significant difference was accepted at 5% level ($P < 0.05$).

RESULTS AND DISCUSSION

The net weight gain of tilapia reared in the enclosed polyhouse using green house model hardly differed ($P > 0.05$) between the outside and enclosed polyhouse with 75 and 50% survival, respectively (Fig.1). The growth reduction of tilapia inside the polyhouse was perhaps attributed to the energy diversion from somatic to temperature induced gonadal activities. It is known that

Table 1. Conditions followed in simulated green house (Polyhouse) experiments performed

Conditions	Enclosed Polyhouse (Enclosed)		Outside Polyhouse (Open)	
	Experment-1	Experiment-2 (pH-7,8,9 & Mix)	Experiment-1	Experiment-2 (Control)
No. of replicates	3	3	3	3
Duration	98 days (8.9.2011 – 17.12.2011)	91 days (13.1.2012 – 16.3.2013)	98 days (8.9.2011– 17.12.2011)	91 days (13.1.2012– 16.3.2013)
Fertilizer used NPK (g tank^{-1}) Cow dung (g tank^{-1}) Poultry droppings (g tank^{-1})	1025-	101515	1025-	—-
Dose of fertilizer	35 g tank^{-1}	40 g tank^{-1}	35 g tank^{-1}	-
Frequency of added fertilizer	7–10 days	once	7–10 days	-
Combination and their no. of fish introduced per tank	Rohu-3, Bata-2, Tilapia – 4 & Paku - 3	Rohu-2, Bata-3, Tilapia-4, Cyprinus-2	Rohu-3, Bata-2, Tilapia – 4 & Paku - 3	Rohu-2, Bata-3, Tilapia-4, Cyprinus-2
No. of fish introduced per tank	12	11	12	11
Light intensity (lux)	15000–30000	20000–40000	65000–75000	70000–90000
Mean air temperature (°C)	42	24	33	20
Mean water temperature (°C)	38	22	33	21

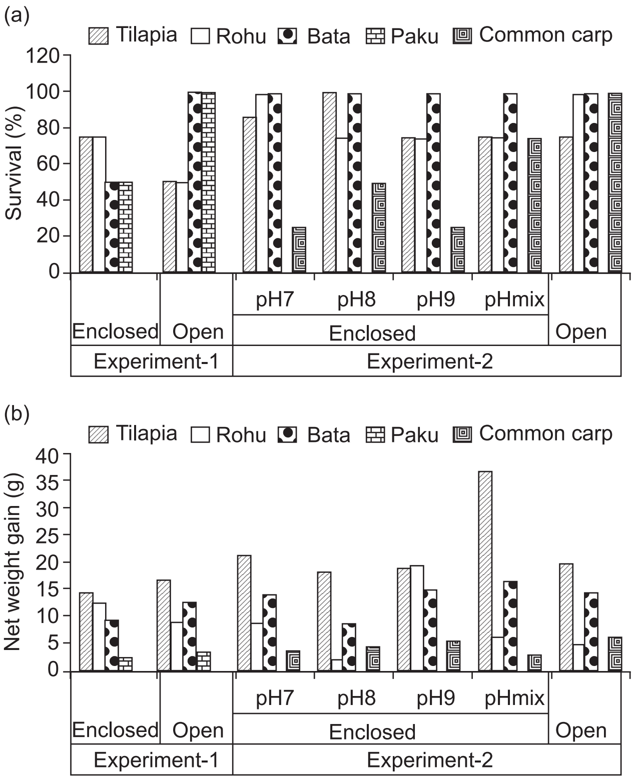

Fig. 1. Survival (a) and net weight gain (b) of different species of fish reared in small holding tanks in enclosed polyhouse and outside in experiment - 1 and experiment – 2.

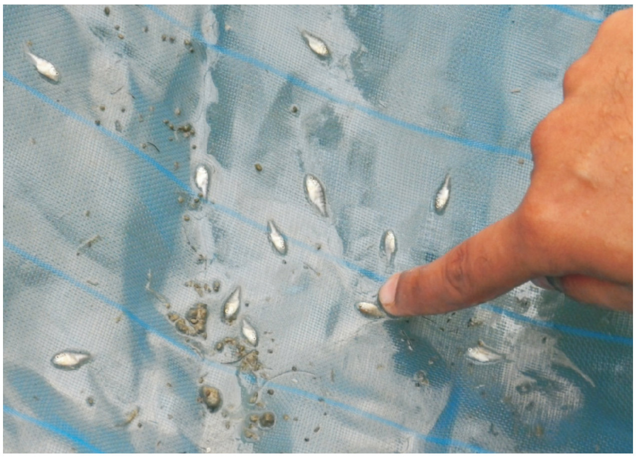

Fig 2. Fry of tilapia procured in tanks placed in enclosed poly house (green house)

many fish, especially tilapia and catfish experience reduction in body weight and food conversion efficiency during later stages of maturity (Shepherd and Bromage 1990). Likewise, no difference ($P > 0.05$) in the growth of other species of test fish was observed between the enclosed and outside system. The responses of carps (rohu, bata, paku and common carp) to different initial pH conditions of water of experimental tanks were not clear cut ($P > 0.05$) between the enclosed and outside the polyhouse (Fig. 1) . The net weight gain of common carp also did not differ ($P > 0.05$) between the enclosed and outside the polyhouse.

In the first trial, tilapia held in enclosed polyhouse tanks bred and produced swim up fry (Fig. 2) whereas, no such fry production was experienced in the tanks held outside the polyhouse. Also in the next trial with different initial pH conditions, production of free swimming fry was recorded in holding tanks of enclosed polyhouse regardless of initial pH conditions of water. Based on the size and average weight of fry at the time of harvest, it appears that breeding activities occurred twice (February and March) during the grow-out period in case of pH -7 and mixed pH conditions with a mean value of pH- 7.9 and 8.0 respectively.

The number of free swimming fry produced per tank ranged from 28 - 36 in different pH conditions (Table 2). On the basis of size and weight of fry, the first batch of fry (average weight - 3.37 g) was clearly distinguished from the second batch having an average weight of 1.5 g. It is likely that the sex ratio of the progeny might have skewed towards male due to constant exposure of fry to polyhouse driven raised-temperature of 26 – 30°C. Experimental evidences suggest that increase in temperature treatment from 27–28°C to 36°C has resulted in increase in per cent of male progeny sex ratio from 49.9 – 55 to 61.4 – 80.6% (Baroiller *et al*. 2009).

In the present study, mean water temperature inside the polyhouse (green house model) ranging from 26°C to 30°C in both the trials favored the breeding activities of tilapia. This temperature range was within the range for tilapia breeding (Anonymous 2003). An ideal permanent water temperature for tilapia farming should be around 27°C and water temperature should not drop below 18°C and not to exceed 34°C (Murnyak 2010). It is also known that tilapia tends to spawn at optimal temperature of 78–84°F (25.5 -

Table 2. Average weight (g) and no. of fry production per tank in enclosed and outside the polyhouse in two experiments performed with green house model during Sep to Mar experiment

Parameters	Experiment- 1 (Sep - Dec)		Experiment-2 (January - March)									
	Enclosed	Open	Enclosed								Open control	
			pH 7		pH 8		pH 9		pH -mix			
	Dec.	Dec.	Feb.	Mar.	Feb.	Mar.	Feb.	Mar.	Feb.	Mar.	Feb.	Mar.
No. of fry/tank	48	0	36	28	0	49	0	45	18	49	0	0
Mean weight (g)	1.5	0	3.12	1.5	0	1.5	0	1.5	3.62	1.5	0	0

Table 3. Range and mean (±SE) of physio-chemical parameters of water in experiment 1 and experiment 2 performed

Parameters	Experiment- 1				Experiment - 2															
					pH-7				pH-8				pH-9				pH-Mix			
	Enclosed		Open		Enclosed		Open		Enclosed		Open		Enclosed		Open		Enclosed		Open	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Water Temperature (°C)	26.9– 38.7	32.94 ±1.09	22– 34	30.24 ±1.16	21.4– 30	25.34 ±.47	21.85– 24.7	23.25 ±.17	21.4– 30	25.34 ±.50	21– 24.85	22.98 ±.18	22.2– 31.3	26.11 ±.53	21.8– 24.9	23.13 ±.20	22.3– 31.05	26.02 ±.53	21.95– 25.15	23.67 ±.20
pH	7.4– 9.75	8.6 ±.18	7.4– 10.12	8.7± .24	7.9– 9.5	8.51 ±.009	7.3– 8.9	8.24 ±.018	8.1– 9.3	8.45 ±.007	8.1– 8.8	8.41 ±.007	7.9– 9.8	8.31 ±.016	8.1– 9.0	8.5 ±.008	8– 9.2	8.54 ±.01	8.4– 9.1	8.76 ±.006
Free CO_2 (mg/l)	0–8	1.14±.34	0–10	2±.54	0–7	1±.3	0–7	1±.3	0–5	0.71±.21	0–0	0±0	0–7	2.71±.32	0–0	0±0	0–6	1.57±.31	0–0	0±0
Total Alkalinity (mg/l)	114.66– 177.33	156.28 ±10.05	86.66– 182	137.33 ±14.12	213– 278	251.57 ±7.33	185– 315	237.56 ±13.98	126– 188	156.42 ±8.01	111– 195	149.57 ±9.94	135– 167	152 ±4.54	110– 233	192.57 ±14.29	165– 206	188 ±5.06	108– 162	144.14 ±5.83
Hardness (mg/l)	100.67– 190.67	154 ±12.25	89.33– 196.67	134.85 ±13.69	176– 216	191.85 ±4.53	161– 184	167.42 ±3.95	123– 173	150.14 ±5.82	112– 152	124.28 ±4.53	126– 173	150.42 ±5.73	85– 190	124.57 ±10.46	153– 195	171.57 ±4.89	111– 152	133.28 ±4.18
PO_4 (mg/l)	1–1.6	1.41 ±.09	.04– 1.79	1.6 ±.07	.72– 1.88	1.25 ±.13	1.3– 1.88	1.56 ±.06	.08– 1.37	0.44. ±.27	07– 1.71	0.5 ±.34	.15– 1.31	0.41 ±.14	.09– 1.62	0.45 ±.19	.38–1.54 ±.14	0.85	.27– 1.36	0.6 ±.15
Chlorophyll (mg/m^3)	0–.28	0.17 ±.03	0– .11	0.04 ±.01	.04 –.17	0.107 ±.02	0– .15	0.04 ±.02	.06 –.17	0.11 ±.01	.01– .11	0.048 ±.01	.08 –.42	0.15 ±.05	.02 –.42	0.106 ±.06	.02 –.12	0.078 ±.01	.03 –.13	0.07 ±.01

28°C) or when water temperature reaches around 24°C. Though the direct impact of raised temperature on tilapia breeding is less known, gonad maturation in common carp has been reported to be stimulated by temperatures in excess of 17°C and preferably of 21–25°C; under such conditions, maturation of eggs takes about 50–70 days (Shepherd and Bromage 1990). Similar responses in egg maturation of tilapia are likely to occur in the present study. According to Lowe-McConnell (1982), factors such as low condition factor, lower water depth or a high fishing intensity could lead to earlier breeding.

Air temperature of enclosed polyhouse remained 6.7°C to 10.6°C higher ($P < 0.05$) than ambient air temperature outside the polyhouse during the period of study (Sep to Dec). The mean air temperature of enclosed polyhouse (39.67°C) was 8.43°C higher than the outside ambient air temperature (31.24°C). In the next trial conducted during Jan to Mar, the differences between inside and outside air temperature became relatively less (4.0°–6.9°C). The average air temperature inside the polyhouse was 4.71°C higher than that of outside.

Water temperature ranged from 26.9°C–38.7°C in culture tanks of enclosed polyhouse against 22°C–34°C outside the polyhouse during the period of study (Sep to Dec; Table 3).

Frequency analysis of water temperature revealed that both minimum and maximum temperature occurred only once (14.28%) during the period of study in the holding tanks of enclosed polyhouse. This showed that polyhouse driven minimum and maximum temperature were 4.9°C and 4.7°C higher than outside temperature. The overall mean temperature for the entire period of study in enclosed greenhouse was 32.23°C (42.85%) against 30.24°C (28.57%) outside ($P < 0.05$).

The polyhouse driven temperature range that occurred most frequently (42.85%) was 32.0° to 32.5°C, whereas its counterpart outside the polyhouse was 1.0°C less (31.0–31.5°C). The green house driven highest temperature range of 38.5–39°C was entirely absent outside, where the highest temperature range was as high as 5°C less (33.0 to 33.5°C) than enclosed polyhouse (Fig.3). Further, the lowest

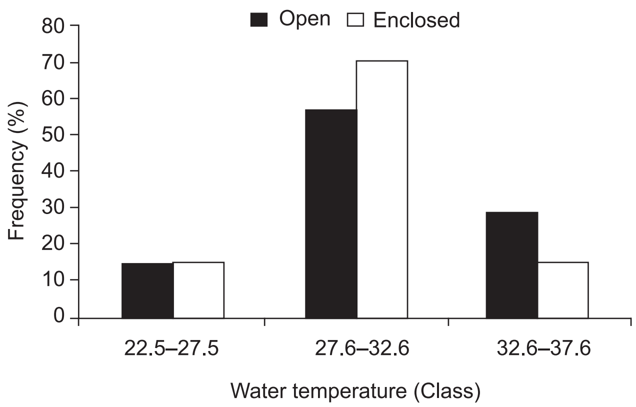

Fig. 3. Frequency of water temperature of experimental tanks in open and enclosed system of polyhouse during experiment - 1 (September - December). Temperature range was made at 5°C intervals.

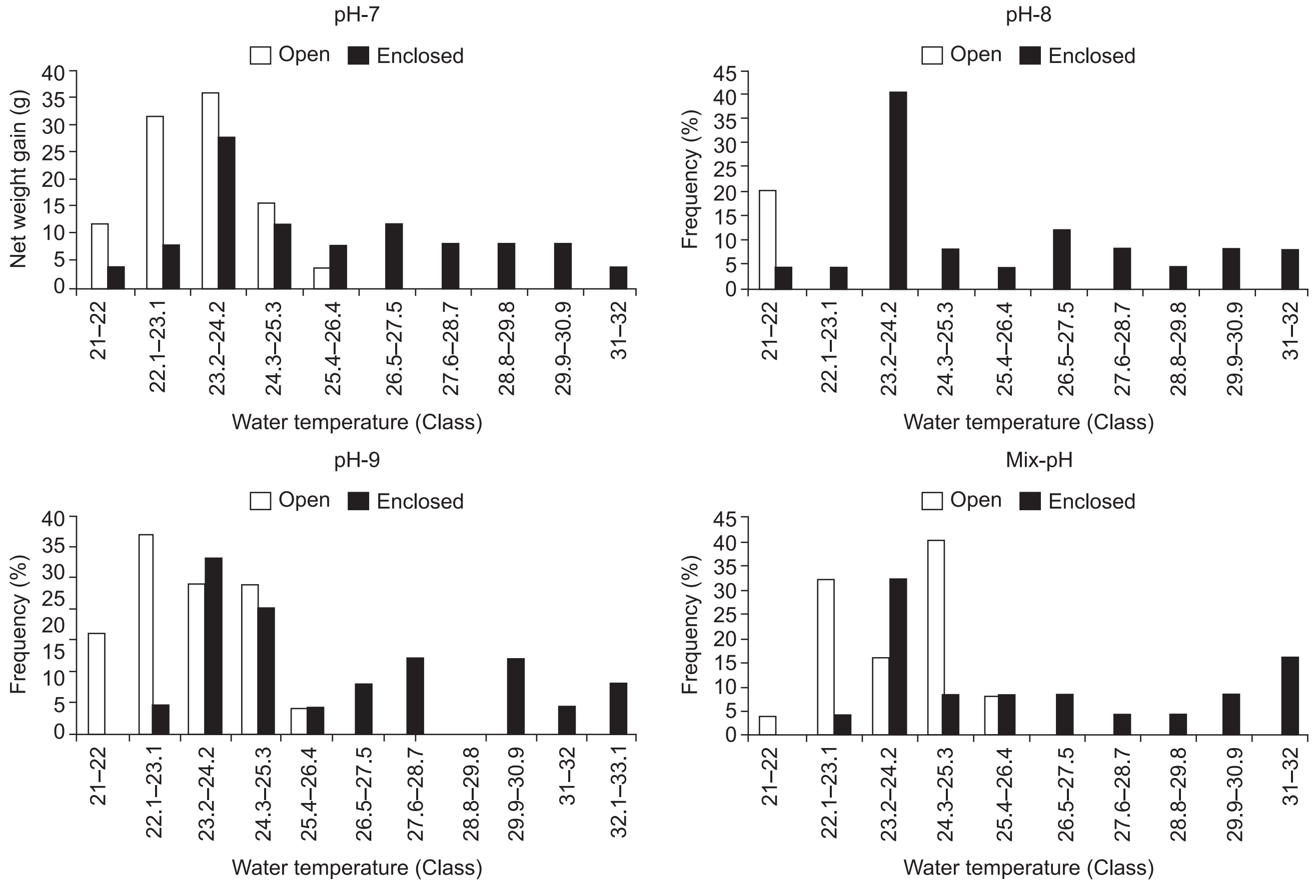

Fig. 4. Frequency of water temperature of experimental tanks with different initial pH conditions in experiment - 2 (January-March).Temperature range was made at 10°C intervals.

temperature range inside the polyhouse was also 5°C higher (27.0 27.5°C) than outside (22.0–22.5°C). The overall mean temperature (32.94°C) of enclosed polyhouse was 2.7°C was higher than outside (30.24°C). This clearly reflects the impact of green house gas emissions of enclosed polyhouse.

In the next trial, even though the minimum temperature did not differ between inside (21.3°C) and outside (21.1°C) the polyhouse, the polyhouse driven maximum temperature (33°C) was as high as 7.2°C higher than outside (25.8°C) (Fig. 4). The maximum temperature range (31.0–32.0°C) of enclosed polyhouse was conspicuous by its absence outside the polyhouse where the highest temperature range (25.4–26.4°C) was 5.6°C less than enclosed polyhouse. The overall mean temperature for all the tanks in different pH conditions was again 2.93°C higher inside (26.21°C) than outside (23.28°C) the polyhouse (Fig.4).

In general, polyhouse driven most frequent (32%) temperature range was 23–24°C, but it was 1°C less (22–23°C) outside the polyhouse which was characterized by the absence of high temperature range of 26 to 32°C. However, such high temperature range was more common (41%) inside the polyhouse. This again shows that polyhouse driven overall mean temperature of water was about 2.93°C higher than outside system.

Mean water pH (Table 3) remained significantly lower ($P < 0.05$) in the tanks placed inside the polyhouse than outside especially in the initial pH conditions of 7 and 9; differences were less marked ($P > 0.05$) at pH - 8 and mix condition. The most frequently occurred pH range inside the polyhouse was 8.0 – 8.6 in first trial (57.14%) (Fig. 5) and 8.5–8.7 in the second experiment (32%) (Fig. 6).

The concentration of free carbon dioxide of water ranged from 0 to 8.0 mg/1 and from 0 to 10.0 mg/l enclosed polyhouse and outside, respectively. The mean concentration of bicarbonate alkalinity of water of enclosed polyhouse was 17% higher (146 mg/l) than outside (124 mg/l) resulting in 13% higher total alkalinity inside (156 mg/l) the polyhouse than outside (Table 3).

In the second trial, the free carbon dioxide of water was absent in most of the samples collected during the period of study (Table 3). However, the mean concentration of carbon dioxide at pH -7 did not differ between enclosed polyhouse (1.0 mg/l) and outside (1.0 mg/l). In the remaining pH (8 and 9) and mixed pH set ups, the mean concentration of carbon dioxide was considerably higher inside (0.71 to 2.71 mg/l) against zero values outside the polyhouse. This shows that effect of green house gases was more accentuated at high pH set ups due to more CO_2 adsorption inside the polyhouse.

The mean concentrations of carbonate and bicarbonate alkalinity of water inside the polyhouse remained higher than outside. An opposite condition was, however,

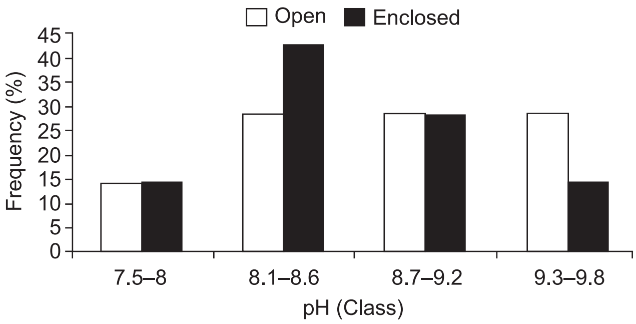

Fig. 5. Frequency of water pH of experimental tanks in open and enclosed system of polyhouse during experiment - 1 (September - December). pH range was made at 0.5 unit intervals.

registered at higher pH (pH- 9) where bicarbonate alkalinity of water remained higher outside than inside (Table 3). The total alkalinity of water of enclosed polyhouse was higher than outside in all the pH conditions except pH 9.

The dissolved oxygen of water in the first experiment (Sep to Dec) remained little less varying in all the culture tanks of enclosed polyhouse than outside. As a result, the mean concentration of dissolved oxygen of water remained about 2 mg/l higher outside (9.43 mg/l) than enclosed polyhouse (7.48 mg/l). The most commonly occurred values were 6.1 to 10.2 mg/l inside and 9.1–11.11 mg/l outside (Fig. 7). This showed that dissolved oxygen of enclosed polyhouse was slightly reduced, it did not limit the fish growth as the values of dissolved oxygen of water remained always far above 4.0 mg/l for good growth of fish.

Polyhouse effects resulted in reduced level of ammonia (0.03 - 0.65 mg/l), nitrite-N and nitrate-N than outside. This showed that both ammonification and nitrification processes were inhibited in the enclosed polyhouse perhaps by the interactions of increased temperature (2°C) and reduced oxygen level of water. On the other hand, the concentration of phosphate, which was significantly higher outside than enclosed polyhouse reflected the more dynamic phosphorus cycle in the former.

Polyhouse driven 3°C (32°C; light intensity- 20,400±17,300 lux) temperature rise resulted in as high as 124% rise in chlorophyll concentration of phytoplankton compared to that of outside (29°C; light intensity - 12,300±7,900 lux) despite the reduced light intensity in the former. The polyhouse driven raised temperature was responsible for the enhanced primary productivity of phytoplankton serving as food for fishes.

Tilapia, popularly called aquatic chicken, is a commonly raised fish throughout the world being second only to carp. It is a plurimodal spawner or multiple spawner with several groups of oocytes in different stages of vitellogenesis. It is the most suitable candidate to the poor farmers in tropical areas because it a multiple spawner, spawning 3 or more

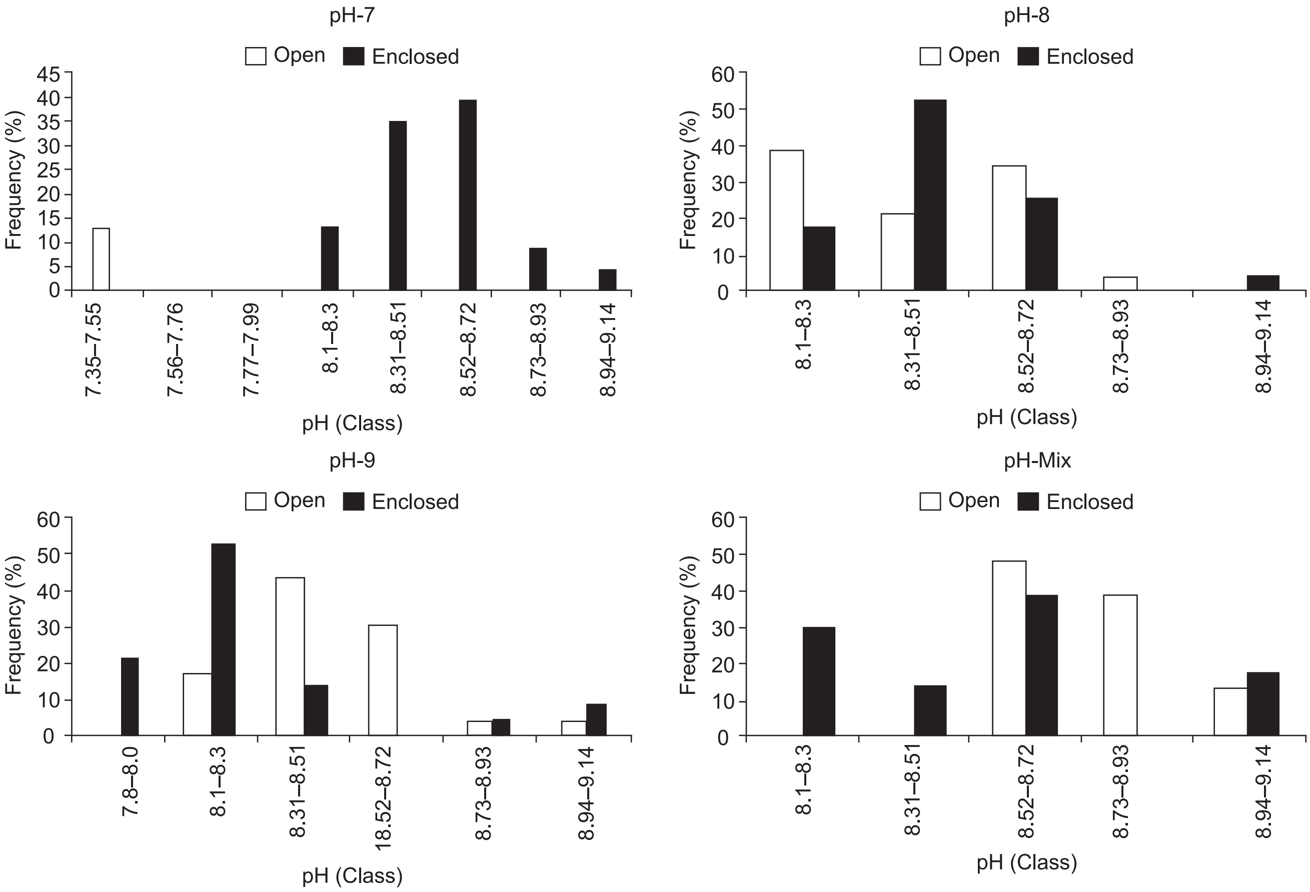

Fig. 6. Frequency of pH of experimental tanks with different initial pH conditions in experiment - 2 (January-March).pH range used at 0.2 unit intervals.

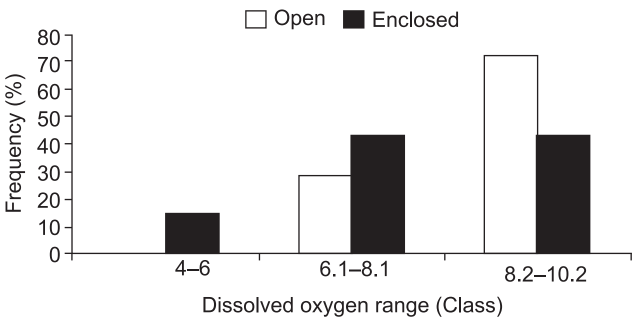

Fig. 7. Frequency of dissolved oxygen of experimental tanks in open and enclosed system of polyhouse during experiment - 1 (September-December).Dissolved oxygen range used at 2 mg/l intervals.

times a year with about 1500–4300 eggs produced per female per year. Tilapia tends to spawn less frequently and less successfully when provided with more dark hours than light hours and the optimal temperature to spawn was between 78–84°F (http://theaquaponicsource.com/2011/03/27).

Since tilapia is a multiple spawner cichlid with mouth brooding habits, it is apparent that the fish was induced to breed in the holding tanks by rising temperature of around 2°C. It is plausible that continuous exposure of raised temperature for 2°C throughout grows out period has stimulated the gonad maturation of tilapia and induced to bred due to thermal response in small holding tanks. The possible mechanism of such induction was mediated through hypothalamus driven gonodotropin releasing hormones that eventually acted on gonads to spawn. In common carp, maturation is stimulated by temperatures in excess of 17°C and preferably of 21–25°C; under such conditions, maturation of eggs takes about 50–70 days (Shepherd and Bromage 1990). Climate change induced water temperature would have a pronounced effect on the reproductive performance of multiple spawner cichlid tilapia capable of breeding in small holding tanks.

The environmental control of spawning are often exhibited in sub tropical and tropical species which are much dependent upon on cycles of temperature or the timing of onset of rainfall (Shepherd and Bromage 1990). For example, De Lapeyre *et al*. (2009) showed that female tilapia (*Oreochromis niloticus*) when kept at 28°C for 7 days and then exposed to 22°C for 7, 14, 28 days followed by restoration of temperature rise to 28°C, exhibited highest spawning rate of 39.5% in 14 day trial against 12.5% in control groups. However, the percentage of hatched and swim-up fry in the 14 and 28 day trials were significantly higher in control groups than in corresponding treatment groups.

Lack of marked difference in body weight of carps (rohu, bata, common carp and paku) between inside and outside the polyhouse was perhaps attributed to the limited space for large-grown carp and duration of grow out period.

It may be reasonably concluded that the benefit of the closed poly-house may be profitably used by the fish farmer for breeding and growth of tilapia and possibly other Indian fishes during winter and colder region of the country in general.

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