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Water temperature enhancement in polyhouse tanks in a sub-tropical region during winter season

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Abstract
An experiment was conducted at ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar during winter season (December to February) of 2011-2012 to observe the variations in temperature and some physico-chemical parameters of water in control and experimental tanks (each with 10 m^2 area and 1.0 m depth). Control tank was without LDPE cover and the experimental tanks were covered with LDPE film of 200µ at different heights (T-1: 0.3 m, T-2: 0.6 m, T-3: 0.9 m) from tank water level. The physico-chemical parameters, such as dissolved oxygen; carbon dioxide; pH of water; and temperature of both air and water were recorded in different durations for different experiments. From the study it was observed that, water temperature rose up to 5.4, 3.6 and 3.2°C in T-1, T-2 & T-3 tanks, respectively than the control one. The other water parameters were found within the acceptable range of fish culture.

Keywords: Polyhouse tanks; Dissolved oxygen; Carbon dioxide; Diurnal variation; Temperature rise

1. Introduction

The aquatic environment governs fish life; hence water quality should be suitable for fish. When environmental condition does not maintain in optimal range for normal fish growth, the fish culture could be affected. The major concerns of the fish culturist should be to deal with the aspects of water quality, which may cause poor growth or death of fish (Boyd, 1978; Piper *et al*., 1982) [3, 14]. To a great extent water determines the success or failure of an aquaculture operation. Water quality is a dynamic web of the physical, biological and chemical factors, which constitute the water environment and influences the production of fish and other aquatic environment. Water quality parameters, which are of prime importance, are mainly temperature, turbidity, dissolved oxygen, CO_2, ammonia, nitrite, nitrate, phosphate, pH, alkalinity, hardness, etc.

Water temperature is the most important factor for the fish growth (Brett & Groves, 1979) [4] and it affects all metabolic and physiological activities of fish and plankton. Water temperature plays an important role in influencing the periodicity, occurrence and abundance of phytoplankton as it had a direct relationship with total plankton (Tripathi and Pandey, 1990; Mohapatra *et al*., 2002, 2007, 2009 & 2012) [16, 10, 11, 12, 13]. Fishes are cold-blooded animals and dependent upon the water temperature in which they live. Generally in low temperature, fish growth hampers due to less metabolic activities. In winter season the growth rate of fish is slow. If we can maintain the water temperature in optimum level in winter season, then their growth rate may not be affected. Water temperature can be maintained at the optimal level favourable to fish growth through greenhouse system (Mohapatra *et al*., 2002, 2007, 2009 & 2012; Tiwari, *et al*., 2007) [10, 11, 12, 13, 15]. In this phenomenon, solar radiation plays a major role to control the water temperature and greenhouse is a good alternative to maintain the water temperature (Zhu *et al.*, 1998) [17]. Greenhouse or plastic shelter ponds could achieve a 2.8-4.4 °C increase in water temperature compared to open-air pond (Klemetson and Rogers, 1985) [9].

It is also observed that dissolved oxygen content of pond water above 5 mg/litre favours good growth of flora and fauna, and it is one of the most important chemical parameters of aquaculture system. Dissolved oxygen concentration in natural water is influenced by the rates of diffusion and from the atmosphere, photosynthesis by aquatic plants and respiration by aquatic biological community (Hutchinson, 1975; Jhingran, 1991) [6, 7].

Carbon dioxide concentrations are maximum during winter and minimum during summer and its presence depends on the pH of water. In spite of high solubility in water, its concentration in most water bodies is low. The primary sources of carbon dioxide in fish ponds are from respiration of fish and the microscopic plants and animals (Jhingran, 1991) [7].

pH is a measure of hydrogen ion concentration in water and it is acidic or alkaline. It has direct effects on fish growth and survival of fish food organisms. Hence, to achieve good fish production, pH of the water should be monitored regularly to ensure its optimum range of 6.5-8.5 (Banerjea, 1967; Jhingran, 1991) [2, 7].

In present study the LDPE film was used to cover the water tanks in winter period to study the physic-chemical parameters of water, such as temperature, pH, dissolved oxygen and carbon dioxide in relation to uncovered tanks and the information aimed for optimum fish growth in polyhouse ponds in winter season.

2. Materials and Methods

The working principle of a polyhouse tank is same as any conventional type of greenhouse. During sunshine hours, total solar radiation received by the LDPE film cover is partly reflected, absorbed and transmitted inside polyhouse through walls and roof. A large portion of transmitted (short wavelength) radiation is absorbed by water through greenhouse effect, and that leads to increase the water temperature. The exposed surface area of the pond absorbs rest part of the radiation. This absorbed thermal energy is further converted, radiated and evaporated into the room air and some heat conducted into the ground. Further, there is heat transfer from greenhouse room air to canopy cover by convection, radiation and evaporation, and finally thermal energy is lost to ambient air by convection and radiation.

The present study was conducted at farm complex of ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar (Latitude 20°15′; Longitude 85° 52′ and altitude 33 m above MSL) during winter season (December to February, 2011-2012). Four cemented tanks of same size (10 m^2 water area and 1.0 m depth) were selected for experiment. One tank was kept without LDPE cover as control (open-air tank) and the rest three tanks were covered with LDPE film of 200μ at different heights from the tank water level *i.e.*, 0.3 m for Tank - 1 (T-1), 0.6 m for Tank - 2 (T-2) and 0.9 m for Tank - 3 (T-3), but were not made air tight (Fig. - 1, Fig. - 2 and Fig. - 3). Height of the LDPE film was maintained by bamboo framed structure erected over the tanks. The tanks were kept free from fish and other culturable animals, but plankton was present. Four types of experiments were conducted.

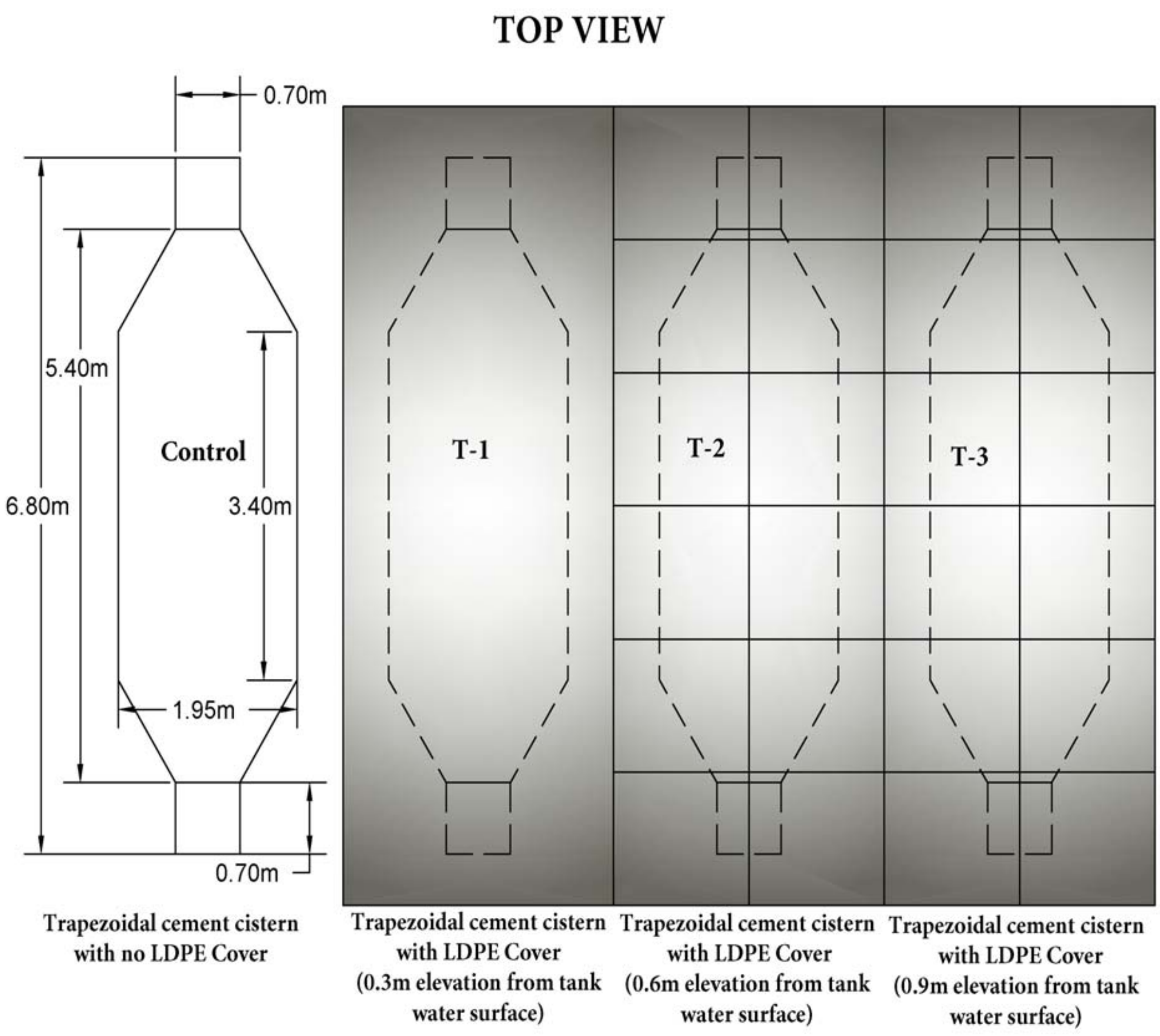

Fig 1: Top view of the polyhouse tanks

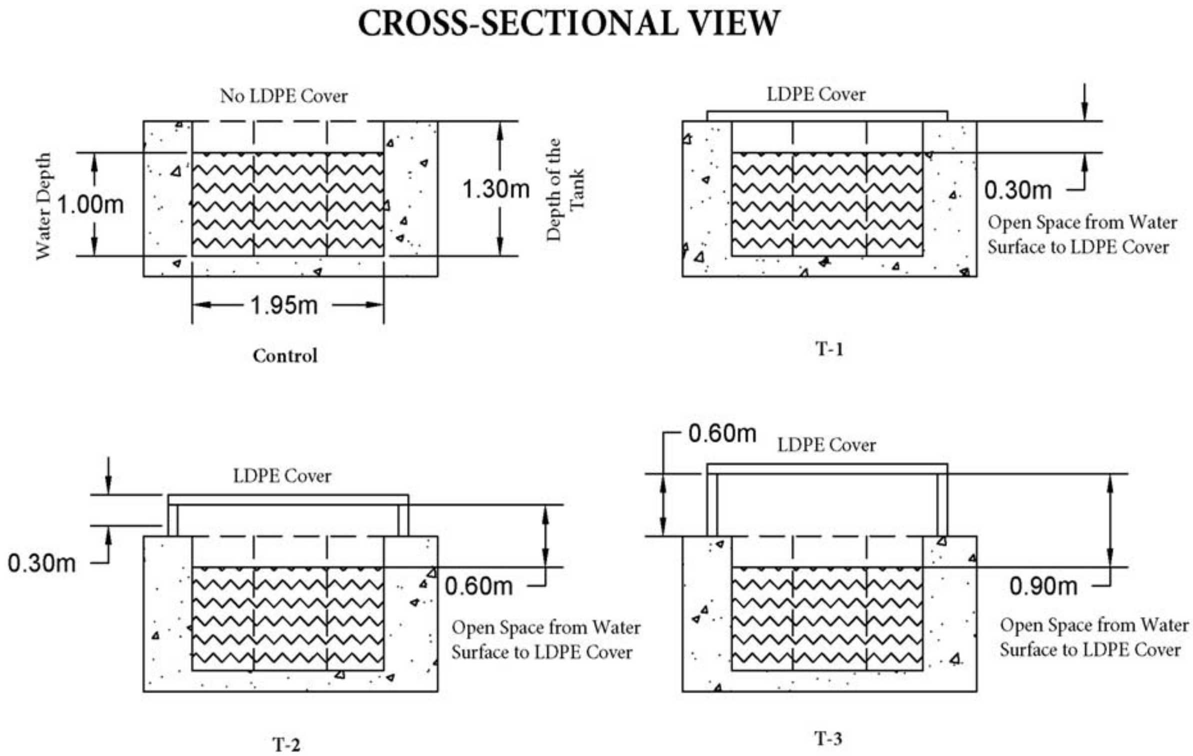

Fig 2: Cross-sectional view of the polyhouse tanks

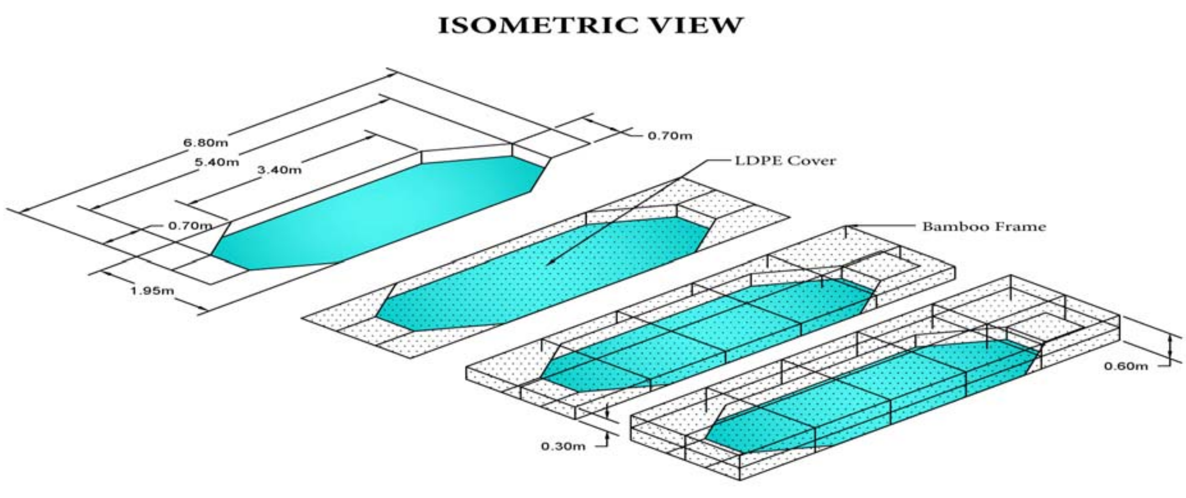

Fig 3: Isometric view of the polyhouse tanks covered with LDPE film

2.1 *Experiment-1*

Temperature of the water and air above the water level were measured for seven days (5 - 11 December, 2011) within 6 AM to 6 PM in 3 hour intervals (6 AM, 9 AM, 12 Noon, 3 PM and 6 PM) from all the experimental and control tanks. It was measured by thermometers.

2.2 *Experiment-2*

Water samples were collected from all the tanks in 3 hour intervals within 6 AM to 6 PM and analysed for temperature, dissolve oxygen (DO), carbon dioxide (CO_2) and pH. The experiment period was 7 days (17 - 23 January, 2012). Water parameters were analysed following the procedure of APHA, 2005.

2.3 *Experiment-3*

Same experimental protocol (as in the case of Experiment – 2) was followed, but the covered LDPE film on tanks was opened for 1 hour for exchange of air in to the tank environment during 6 AM to 7 AM. This experiment duration was for 7 days (26 January - 1 February, 2012).

2.4 *Experiment-4*

Diurnal variations of water parameters were conducted in two different days (6 - 7 January, 2012 and 12 - 13 January, 2012). Water samples were collected from all the tanks in 3 hour intervals in a day (6 AM to 6 AM of next day) and the samples were analysed.

3. Results and Discussion

3.1 *Experiment-1*

The air and water temperature data taken from the experimental tanks for seven days are given in Table - 1. The air and water temperature in polyhouse tanks were recorded higher than that of open-air tank throughout the experimental period. This was due to heating of water by greenhouse effect and simultaneous reduction of thermal loss during night hours. The maximum variation of temperature of water in greenhouse and open-air tanks was recorded at 3.00 PM of the day and minimum temperature was in the morning hour at 6.00AM.

Table 1: Temperature variation in experimental tanks (5 - 11 December, 2011)

Time	Control		Tank -1		Tank -2		Tank -3	
	Air temp (°C)	Water temp (°C)	Air temp (°C)	Water temp (°C)	Air temp (°C)	Water Temp (°C)	Air temp (°C)	Water temp (°C)
6.00 AM	17.96±0.53	23.41±0.61	23.66±0.45	26.83±0.46	21.27±0.71	25.96±0.47	21.04±0.65	25.69±0.37
9.00 AM	26.0 ±1.10	23.9±0.18	26.07±1.26	27.03±0.50	28.29±1.77	26.16±0.59	28.46±0.98	25.97±0.46
12.00 Noon	31.57±0.98	25.59±0.30	31.34±0.82	29.16±0.75	32.66±1.33	27.99±0.64	32.44±1.24	27.87±0.21
3.00 PM	30.73±1.55	25.86±0.47	31.16±0.83	30.39±0.65	31.94±1.39	28.74±0.76	31.23±1.08	28.41±0.80
6.00 PM	23.13±0.74	25.2±0.27	26.8±0.24	29.24±0.29	24.79±0.31	28.41±0.68	24.30±0.36	27.90±0.45

3.2 *Experiment-2*

The values of water parameters taken from the experiments are given in the Table - 2. Water quality parameters such as dissolved oxygen, pH and free carbon dioxide were found non-significantly similar in both the control and polyhouse experimental tanks. These values were in the acceptable range for the fish rearing. However, dissolved oxygen concentration was recorded lower in polyhouse pond than the open-air pond in the morning hours. Water temperature was higher in polyhouse tanks than open-air tank and ranged from 23.4 °C-30.6 °C during experimentation period. Temperature was recorded higher both in air and water at 3.00 PM of the day. Carbon dioxide was recorded nil (0 ppm) and pH above 8.4 during at 3.00 PM of the day.

Table 2: Water parameters of experimental tanks (17 - 23 January, 2012)

Time	Tanks	Air temp (°C)	Water temp (°C)	DO (mg/l)	CO_2 (mg/l)	pH
9.00 AM	Controlled	25.83 ±1.28	22.96±0.62	6.77±2.06	4.00±5.03	8.71±0.60
	T-1	28.80±0.91	27.19 ±0.15	6.51 ±0.32	3.14 ±3.24	8.39 ±0.18
	T-2	30.67±1.58	26.30±0.48	5.49±0.41	9.14±1.07	8.16±0.10
	T-3	30.91±1.68	25.59±0.34	5.09±0.70	9.14±1.95	8.10±0.08
3.00 PM	Controlled	28.81±1.83	25.39±0.91	7.26±0.86	2.86±5.40	8.78 ±0.44
	T-1	29.99±1.57	31.50±2.26	5.34±0.40	0.29±0.76	8.47±0.10
	T-2	30.94±2.49	28.10±0.41	7.49±0.64	0.00±0.00	8.59±0.10
	T-3	31.17±0.43	27.44±0.26	7.23±0.58	0.00±0.00	8.60±0.07

3.3 *Experiment-3*

The data of water parameters taken from experimental tanks are given in the Table - 3. It was found that T-1 had higher temperature than T-2, T-3 and control. Water parameters were found non-significantly similar in both the control and polyhouse experimental tanks.

Table 3: Physico-chemical parameters of water with 1 hour (6.00 AM - 7.00 AM) opening of polyhouse to open air (26.01.12 - 01.02.12)

Time	Tanks	Air temp (°C)	Water temp (°C)	DO (mg/l)	CO_2 (mg/l)	pH
9.00 AM	Controlled	23.39±1.97	22.57±0.77	3.46±0.87	9.71±2.43	8.26±0.08
	T-1	25.76±1.39	27.57±1.20	2.83±0.39	5.71±4.39	8.30±0.08
	T-2	25.13±2.36	25.89±1.15	2.17±1.04	9.43±2.23	8.11±0.08
	T-3	26.93±1.97	25.70±0.95	1.94±0.78	9.43±2.23	7.92±0.05
3.00 PM	Controlled	27.26±2.64	23.84±0.95	4.66±0.34	0.00±0.00	8.42±0.09
	T-1	28.59±0.66	29.44±1.87	3.83±0.65	0.00±0.00	8.43±0.04
	T-2	26.69±1.78	27.57±1.02	4.14±0.70	0.00±0.00	8.58±0.06
	T-3	27.86±2.31	26.74±2.45	3.69±1.04	0.00±0.00	8.57±0.06

3.4 *Experiment-4*

Diurnal study was conducted in a regular time interval of 3 hours in two different days in different weather condition; one (day-1: 6 - 7 January, 2012) with cloudy weather with visibility: 2.5 kilometres, temperature: 22-33 °C, humidity: 48-94% and the second day (day-2: 12 - 13 January, 2012) with visibility: 2.2 kilometre, temperature: 13-25 °C, and humidity: 30-87 %.

In diurnal study (day-1), pH in all the tank water was ranged from 7.7-8.4. Maximum dissolved oxygen level was recorded in the open-air tank during afternoon hours. Dissolved oxygen in greenhouse tank ranged from 3.6 to 6.4 ppm and free carbon dioxide value ranged from 0 to 20 ppm. The highest free carbon dioxide value was recorded in the morning hours in T-2 & T-3. Water temperature of polyhouses was higher than the open-air tank. Water temperature was recorded lowest at 6 AM in control tank (23.6 °C) followed by T-3 (24.6 °C), T-2 (25.9 °C) and T-1 (26.4 °C) and higher temperature at 3 PM in T-1 (30.4 °C) followed by T-2 (28.2 °C), T-3 (27.7 °C) and controlled tank (27.5 °C). The data of diurnal variation of water parameters on 6-7 January, 2012 is given in the Table - 4 and Fig. - 4.

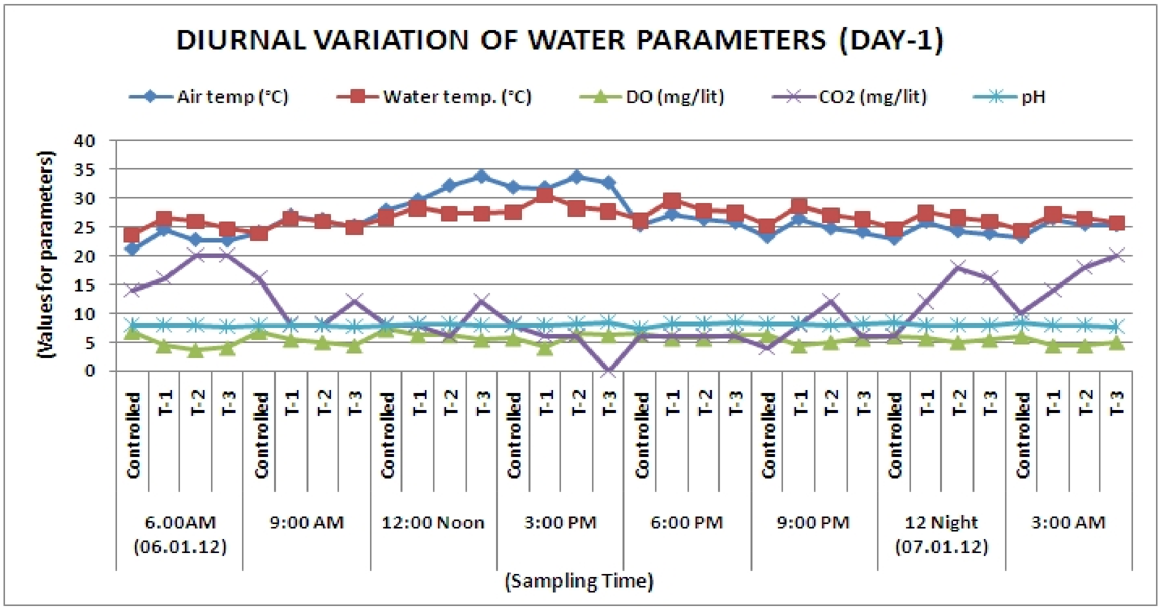

Fig 4: Graphical representation of water parameters of diurnal variation of Day - 1

Table 4: Physico-chemial parameters of water during diurnal variation study in a cloudy day (6 - 7 January, 2012)

Date & Time	Tanks	Air temp (°C)	Water temp. (°C)	DO (mg/l)	CO_2 (mg/l)	pH
6.00AM (06.01.12)	Controlled	21.1	23.6	6.8	14	7.8
	T-1	24.5	26.4	4.4	16	7.9
	T-2	22.7	25.9	3.6	20	7.8
	T-3	22.6	24.6	4	20	7.7
9 AM	Controlled	24	23.8	6.8	16	7.9
	T-1	26.9	26.5	5.4	8	7.9
	T-2	26.2	25.9	5	8	7.8
	T-3	25.1	24.8	4.4	12	7.6
12 Noon	Controlled	27.8	26.6	7.2	8	7.8
	T-1	29.6	28.2	6.2	8	8.1
	T-2	32.1	27.2	6.2	6	8.2
	T-3	33.7	27.3	5.4	12	8.0
03 PM	Controlled	31.8	27.5	5.6	8	7.8
	T-1	31.7	30.4	4	6	8.0
	T-2	33.6	28.2	6.4	6	8.1
	T-3	32.6	27.7	6.2	0	8.4
06 PM	Controlled	25.2	26.1	6.4	6	7.4
	T-1	27.2	29.5	5.6	6	8.1
	T-2	26.3	27.8	5.6	6	8.2
	T-3	25.7	27.4	6.2	6	8.3
09 PM	Controlled	23.2	25.1	6.2	4	8.2
	T-1	26.4	28.6	4.4	8	8.1
	T-2	24.7	27.00	5	12	8.0
	T-3	24.1	26.3	5.6	6	8.2
12 Night (07.01.12)	Controlled	22.9	24.6	6	6	8.3
	T-1	25.9	27.4	5.6	12	8.0
	T-2	24.2	26.6	5	18	7.8
	T-3	23.8	25.9	5.4	16	8.0
3 AM	Controlled	23.2	24.4	6	10	8.3
	T-1	26.4	27.1	4.4	14	7.8
	T-2	25.4	26.5	4.4	18	7.8
	T-3	25.3	25.7	5	20	7.7

In diurnal study of day - 2 (12 - 13 January, 2012), the water temperature was higher in polyhouse tanks than the open-air tank. The water temperature was recorded higher at 3 PM in T-1 (28.7 °C) followed by T-2 (26.1 °C), T-3 (25.5 °C) and control tank (23.3 °C) and the lowest water temperature was recorded at 6 AM in control tank (21.2 °C) followed by T-3

(23.6 °C), T-2 (24.4 °C) and T-1 (25.4 °C). pH of water in all the tanks ranged between 7.5 and 9.1. Maximum dissolved oxygen level was found in the open-air tank during afternoon hours. Dissolved oxygen in polyhouse tank ranged from 4.0 to 7.2 ppm and free carbon dioxide values ranged from 0 to 20 ppm. The highest free carbon dioxide value was recorded in the morning hours in T-3. The data of diurnal variation of 12 - 13 January, 2012 are given in Table - 5 and graphically in Fig. - 5.

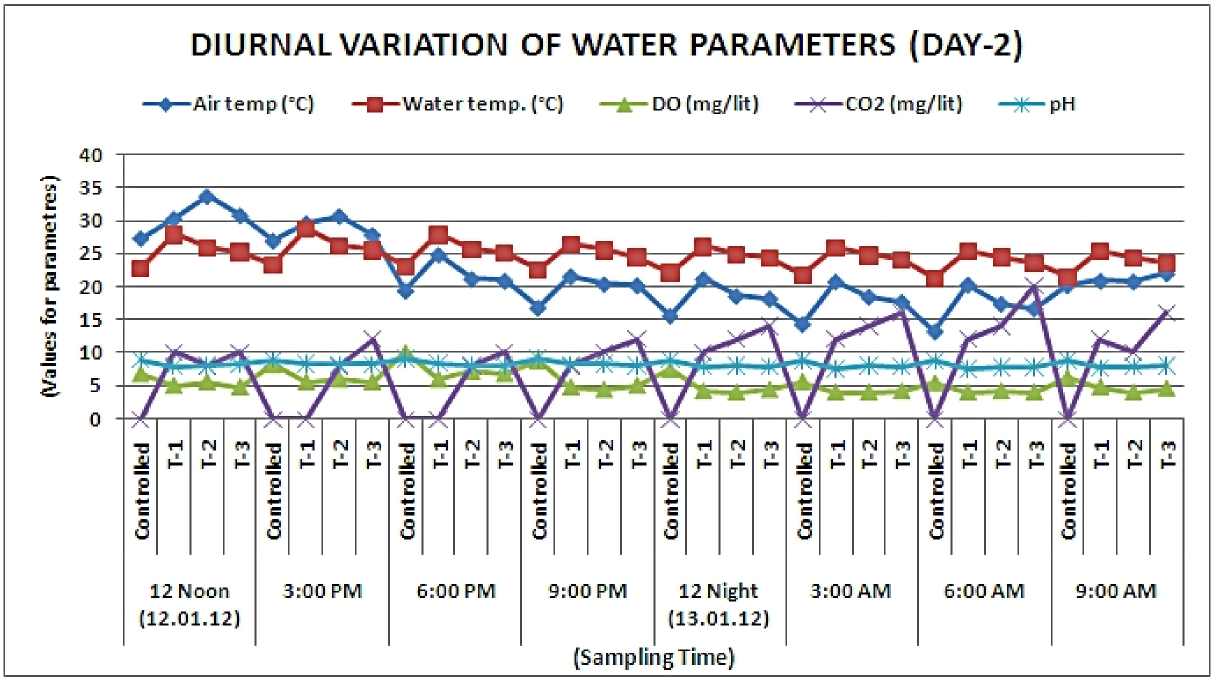

Fig 5: Graphical representation of water parameters of diurnal variation of Day - 2

Table 5: Physico-chemial parameters of water during diurnal variation study in a cold spell day (12 - 13 January 2012)

Date & Time	Tanks	Air temp (°C)	Water temp. (°C)	DO (mg/l)	CO_2 (mg/l)	pH
12 Noon (12.01.12)	Controlled	27.3	22.7	6.8	0	8.9
	T-1	30.3	27.8	5.0	10	7.9
	T-2	33.7	25.8	5.6	8	8.1
	T-3	30.8	25.2	4.8	10	8.2
03 PM	Controlled	26.9	23.3	8.2	0	8.9
	T-1	29.6	28.7	5.6	0	8.3
	T-2	30.7	26.1	6.0	8	8.2
	T-3	27.8	25.5	5.6	12	8.2
06 PM	Controlled	19.3	22.9	10	0	9.1
	T-1	24.8	27.8	6.0	0	8.4
	T-2	21.1	25.6	7.2	8	8.1
	T-3	20.8	25.0	6.8	10	8.0
09 PM	Controlled	16.7	22.5	8.8	0	9.0
	T-1	21.5	26.4	4.8	8	8.2
	T-2	20.3	25.5	4.4	10	8.3
	T-3	20.1	24.4	5.0	12	8
12 Night (13.01.12)	Controlled	15.5	22.1	7.4	0	8.9
	T-1	21.1	26.0	4.2	10	7.9
	T-2	18.5	24.9	4.0	12	8.0
	T-3	18.1	24.3	4.4	14	7.9
3 AM	Controlled	14.2	21.7	5.6	0	8.8
	T-1	20.7	25.8	4.0	12	7.5
	T-2	18.4	24.7	4.0	14	8.0
	T-3	17.6	24.0	4.2	16	7.9
6 AM	Controlled	13.1	21.2	5.4	0	8.7
	T-1	20.2	25.4	4.0	12	7.6
	T-2	17.3	24.4	4.2	14	7.8
	T-3	16.6	23.6	4.0	20	7.8
9 AM	Controlled	20.1	21.5	6.2	0	8.8
	T-1	20.8	25.3	4.8	12	7.7
	T-2	20.7	24.3	4.0	10	7.9
	T-3	21.9	23.6	4.6	16	8.0

Klemetson and Rogers (1985) [9] could achieve 2.8-4.4 ºC increase in water temperature for each month of the year in greenhouse or plastic shelter pond when compared with an open-air pond. According to Brooks and Kimball (1983) [5], 9.0 ºC rise in water temperature could be achieved in January in Phoenix, USA in a solar heated aquaculture pond. According to Joshi and Tyagi (2008) [8] the air temperature in polyhouse was 6.05 °C higher than the control in morning (minimum range), while it was 9.24 °C higher in the afternoon (maximum). Likewise the water temperature in the polyhouse covered pond rose 7.06 °C in morning and 10.96 °C at after noon, than the control pond. Mohapatra *et al.* (2002, 2007, 2009 & 2012) [10, 11, 12, 13] also found similar results in greenhouse pond waters at ICAR-CIFA farm at Bhubaneswar in winter months and the temperature hike over open-air ponds ranged between 3.1-7.0ºC. In the present study it was observed that, the water temperature rose up to 5.4, 3.6 and 3.2°C in T-1, T-2 & T-3 tanks respectively than the control one. The water temperature in greenhouse pond was recorded higher than that of open-air pond throughout the experimental period. This was due to heating of water by greenhouse effect and simultaneous reduction of thermal loss during night hours.

According to Mohapatra *et al.,* 2007, 2009 & 2012, during diurnal study in polyhouse tanks the maximum water temperature was recorded in afternoon hours *i.e.,* 3 & 4 PM of the day and minimum temperature was in the morning hours at 4 & 5 AM. Similar results were also found in the present diurnal experiments with maximum temperature at 3 PM and minimum at 6 AM.

The values of water parameters such as dissolved oxygen, pH and free carbon dioxide in the present study were found non-significantly similar in both the control and polyhouse experimental tanks. These values were found in the acceptable range for the fish rearing. In experiments conducted in polyhouse ponds at ICAR-CIFA farm, Bhubaneswar Mohapatra *et al.,* 2002, 2007 & 2009 could report higher phytoplankton and fish production in polyhouse ponds than open-air ponds. The higher growth and survival of common carp fry, rohu and prawn were observed in polyhouse ponds. Mohapatra *et al.,* 2002, 2007, 2009 & 2012 also reported that the chemical water parameters did not show any difference between polyhouse and open-air ponds. In the present experiment the water parameters showed the similar results.

4. Conclusion

From the current study, it is being concluded that the water temperature was higher in polyhouse tanks in comparison with the open-air tank. In T-1 tank (with LDPE cover 0.3 m height over the tank water surface), temperature was generally higher than the others. All the water parameters analysed were near optimal level and found suitable for fish rearing during winter months. Hence, it is recommended that in open ponds, where temperature falls to low level in winter season can be used with LDPE plastic covers on them for maintaining water temperature and water quality parameters for fish rearing.

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