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Influence of greenhouse technology on selected pond water quality parameters and growth performance of Nile tilapia in high altitude areas

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Abstract
Current study investigated the impact of greenhouse on selected water quality and growth parameters of Nile tilapia. Fingerlings were cultured and uniformly fed on isonitrogenous diet for six months in greenhouse and open ponds. At the end of experiment, Greenhouse pond had significantly higher temperatures than open pond. Mean dissolved Oxygen, pH and conductivity in the two ponds compared insignificantly. The concentrations of ammonium and Nitrate were higher in the greenhouse pond while Nitrites, soluble reactive phosphorus and total phosphorus in two ponds compared insignificantly. Final weight, Specific and Absolute growth rates and condition factor of Nile tilapia in greenhouse pond were significantly higher compared to open pond. This study recommends adoption of greenhouses in Nile tilapia aquaculture in high altitude areas. Current findings will be useful to aquaculture practitioners aiming to improve Nile tilapia performance and other warm water fish species in high altitude areas characterized by low temperatures.

Keywords: Greenhouse, water quality, growth parameters

Introduction
In aquaculture, water quality stands among the most important factors influencing the survival, growth, reproduction and development of fish and the overall management of the culture systems [1]. The main objective of water quality management in aquaculture is to have improved growth rates of fish through improved feed utilization efficiency as well as fish survival hence optimal production performance. This will eventually results into reduced production costs in terms of time and money [2]. Deterioration in water quality can result in poor feed intake and conversion efficiency, fish are stressed and become vulnerable to diseases which can result to poor growth rates [3]. Furthermore, the increased cost of production due to management problems are directly related to poor water quality and in severe cases it results into fish kills [4].

Water quality includes all biological, physical, and chemical variables which influence the beneficial use of water [5]. Physical and chemical variables of water quality includes aspects of Dissolved oxygen, salinity, ammonia nitrogen, nitrites, nitrates, chlorine, pH, conductivity, turbidity etc. collectively, physical chemical parameters of water quality directly affects growth of fish by influencing the rates of metabolism, reproduction, life cycles and health of fish [6, 7].

Temperature has been found to be critical in determining the concentration level of most physical chemical factors. Furthermore, water temperature affects all physiological processes of fish [8, 9]. Under natural conditions, Nile tilapia (warm water fish) production is higher in warmer season of the year when temperatures are within optimal range. In low temperature zones and seasons, the metabolic activities of Nile tilapia are usually reduced which negatively affects their growth [8]. To improve production in such regions/seasons, supplementary heat is inevitable. There are several methods/infrastructures for thermal regulation that has been tested with various success stories being reported

The selection of aquaculture production technology to be employed in improving thermal energy are based on their impact on water quality [10]. In high altitude for instance, the areas are characterized by low temperatures below the recommended range of 21-29 ˚C hence not favourable for optimal growth of warm water fish species like Nile tilapia [11].

In such areas, greenhouse is one of the technologies used to control temperature and humidity to boost aquaculture by preventing drastic drop or rise of temperature [12]. Furthermore, studies indicate that water temperature in greenhouses can be increased by 3-9 °C [13]. However, scanty information exists on the impact of the greenhouses on other aspects of water quality and eventually growth performance of Nile tilapia which the current study aims to evaluate.

Materials and Methods

Description of the Study Area

The study was conducted at the Agro-Science Park's Fish Farm within Egerton University (figure 1). The university is situated at an altitude of 1,800m above sea level and has a geographical reference of S 0˚22'11.0", E 35˚55'58.0" within the Kenyan Rift valley at Njoro, Nakuru County. Temperatures in Njoro region range between 17 ˚C and 22 ˚C on average and drop to 11 ˚C during cold season. Average annual rainfall received in the area is upto 1,200±100 mm.

Fish growth experimental design

The experiment was conducted in an open and greenhouse ponds. A total of 240 monosex male tilapias averaging 4.96±0.27g were stocked. Fifteen hapa nets each measuring (2m×1m×1m) were set up in each pond and stocked with 8 fingerlings per net. The fingerlings were fed on a 35% isonitrogenous diet for a period of six months (January to June 2017), at a rate of 3% body weight per day. The amount was adjusted after every two weeks when the fish were sampled for weight gain. Fish feeding was done by hand twice a day at 1000hrs and 1600hrs.

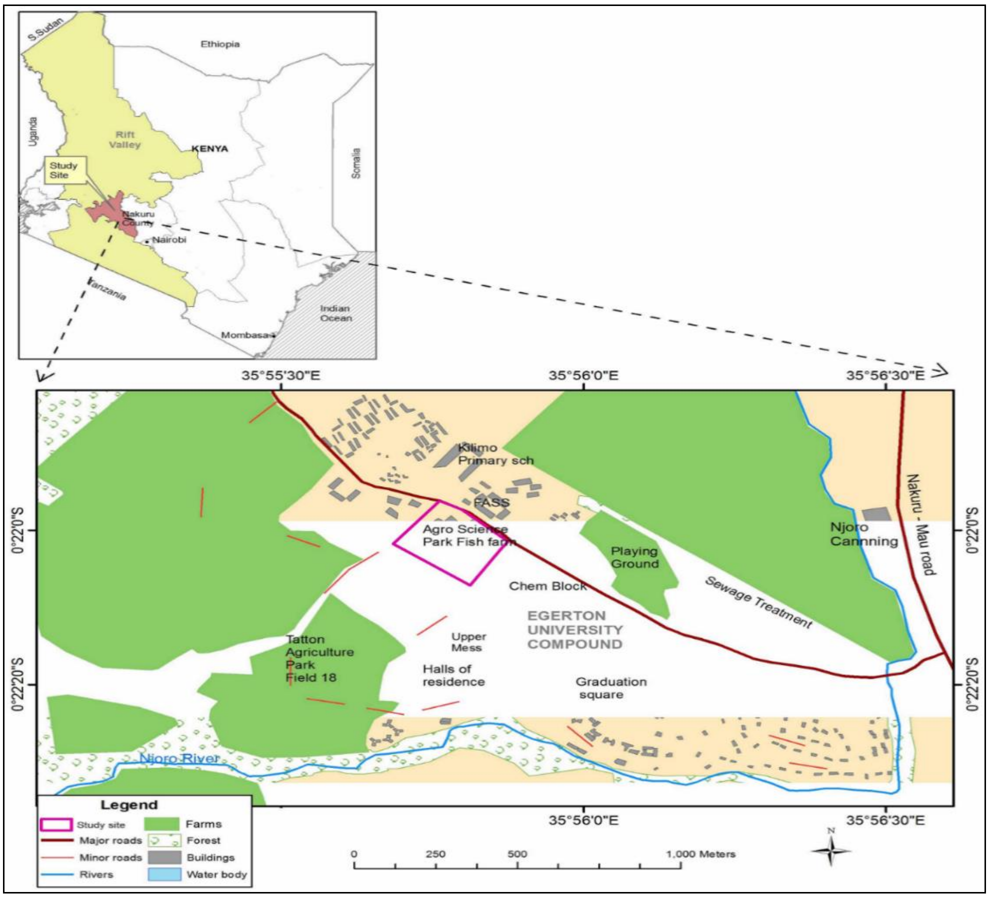

Fig 1: A map of Egerton University showing the site where experimental ponds are located.

Water samples collection and analysis

Selected physico-chemical parameters which include temperature (°C), conductivity (μScm^{-1}), dissolved oxygen (mgL^{-1}) and pH were measured *in situ* daily at 0800hrs using Multi-probe HQ40D meter (HACH LDO; PHC301 & CDC41) at three selected points (deep end, shallow end and middle of pond). Water samples were collected in duplicate and taken to water quality laboratory for analysis at biological science department, Egerton University. Nutrients, Nitrogen (Ammonium-nitrogen NH_4-N, Nitrite nitrogen NO_2-N and Nitrate-nitrogen NO_3-N) and Phosphorus (Soluble Reactive Phosphorus SRP and Total Phosphorus TP) were determined calorimetrically and their concentrations calculated from known concentrations of standard solutions as described by American Public Health Association [14].

Sampling and evaluation of growth performance

Fish sampling for weight gain was done after every fortnight. Five (5) fish were randomly sampled from each net. Body weight (g) and length (cm) were measured using a digital weighing balance and fish measuring board, respectively. To evaluate the impact of the greenhouse on fish growth, the performance indices of weight gains, absolute growth rate (AG) and specific growth rate (SGR) of fish were calculated as per the equations 1, 2 and 3.

$$Weight\ gain = Final\ weight - initial\ weight \quad (1)$$

$$Absolute\ growth\ = \frac{Wf - Wi}{T} \quad (2)$$

$$Specific\ growth\ rate = \frac{In(final\ weight) - In(initial\ weight)}{time\ interval\ in\ days} \times 100\% \quad (3)$$

Where, wf, wi, T and *In* represents Final weight, Initial weight, Time and Natural logarithm

Length-weight relationship and Fish condition factor

Fish condition factor (K) was determined from the length-weight relationship [15] as shown in equation 4.

$$W = aL^b \qquad (4)$$

Where: W is the weight of fish (g), L is the total length of fish (cm), a is the Rate of change of weight with length and b is the weight at unit length.

The condition factor (K) was determined using equation 5[16]:

$$K = \frac{100W}{L^b} \qquad (5)$$

Data management and analysis

Microsoft excel 2016 was used to store and analyse data. Descriptive statistics: means and standard deviation (SD) were used in reporting the findings. Student's t-test was used to compare means of physico-chemical parameters, weight gains, absolute growth rate, specific growth rate and condition factor of Nile tilapia from two pond systems. In all statistical analyses, 5% level ($P<0.05$) of significance was used.

Results

Physico-chemical parameters

Quantitative data for the analysed physical and chemical parameters are presented in table 1. There was a significant difference in the mean daily temperature recorded in the two pond systems (t-test, $p<0.05$). Greenhouse recorded a mean daily temperature of 23.56±1.74 ˚C with a maximum temperature of 27.13 ˚C and minimum of 20.90 ˚C while the open pond had mean temperature of 18.72±2.09 ˚C with maximum temperature of 24.40 ˚C and minimum of 15.60 ˚C recorded.

There was no significant difference in the oxygen concentration values recorded in the two pond systems (t-test, $p>0.05$). In the greenhouse pond, oxygen concentration was between a maximum and minimum of 8.34mg/L and 1.38mg/L respectively. The mean oxygen concentration in the greenhouse pond was 3.25±1.0mg/L. Open pond environment recorded a maximum and minimum oxygen concentration of 9.3mg/L and 2.06mg/L respectively with a mean oxygen concentration of 3.57±2.3mg/L.

In the greenhouse environment, the recorded pH ranged from 7.45 to 9.22 while the open pond environment had pH values ranging from 7.76 to 9.86. Open pond had much wider pH range of 2.10 compared to greenhouse pond with pH range of 1.77. Electrical conductivity values recorded in the two pond systems had no significant difference (t-test, $p>0.05$). The values recorded in the open pond environment were lower compared to greenhouse pond. Open pond recorded a mean conductivity value of 500.15±39.81 µs/cm while the greenhouse environment had a mean conductivity value of 578.07±21.02 µs/cm.

Nutrients concentration

Analysis of Nitrogen components (Ammonium, Nitrite and Nitrate) showed variations in the two ponds. Ammonium concentrations in the two ponds had a significant difference (t-test, $p<0.05$). Higher concentration of ammonium with mean value of 0.42±0.03mg/L was recorded in the greenhouse compared of 0.21±0.02mg/L ammonium recorded in the open pond system.

Table 1: Summary of physical chemical parameters in greenhouse pond and open pond during experimental period

	Pond Type	
Parameter	**Open**	**Greenhouse**
Temp (˚C)	18.72±2.09^a	23.56±1.74^b
Oxygen (mg/L)	3.57±2.31^a	3.25±1.04^a
pH	7.76-9.86	7.45-9.22
Cond (µs/cm)	500.15±39.81^a	578.07±21.02^a
Ammonium (mg/L)	0.21±0.02^a	0.42±0.03^b
Nitrite (mg/L)	0.03±0.01^a	0.02±0.01^a
Nitrate (mg/L)	0.05±0.01^a	0.03±0.01^b
SRP (mg/L)	0.12±0.02^a	0.13±0.02^a
TP (mg/L)	0.49±0.03^a	0.61±0.05^a

Values in the same raw with different superscripts have significant difference.

Nitrite-Nitrogen concentrations from the two pond systems had no significant difference (t-test, $p>0.05$). Nitrite concentration in open pond was higher with mean value of 0.03±0.01mg/L compared to the mean of 0.02±0.01mg/L in the greenhouse pond. Nitrate concentrations in the two ponds had a significant difference (t-test, $p<0.05$) with highest mean value in the open pond. Nitrate had means of 0.05±0.01mg/L and 0.03±0.01mg/L in the open pond and greenhouse pond respectively.

Soluble reactive phosphorus and Total Phosphorus did not vary significantly in the two pond (t-test, $p>0.05$). The concentrations in the greenhouse pond were higher compared to open pond. SRP had a mean concentration of 0.12±0.02mg/L and 0.13±0.02mg/L while TP had mean concentration of 0.49±0.03mg/L and 0.61±0.04mg/L in the open pond and greenhouse pond respectively.

Fish Growth

The final weight and overall mean weight gain of Nile tilapia in the greenhouse was statistically different from those in the open pond (t-test, $p<0.05$). Nile tilapia in the greenhouse pond attained the highest final weight of 246.74±1.96g while in the open pond final weight attained was 57.89±2.61g. These represented a mean weight gain of 244.72±1.21g and 55.86±1.04g in the greenhouse and open pond, respectively. The calculated absolute growth of Nile tilapia cultured in the two pond systems was statistically significant (t-test, $p<0.05$).

Nile tilapia in greenhouse pond had mean absolute growth rate of 1.39±0.01. This value was higher than 0.31±0.02 absolute growth rate of Nile tilapia in the open pond system. The specific growth rate of Nile tilapia cultured in the greenhouse pond was significantly higher to that of open pond. In the greenhouse pond Nile tilapia had specific growth rate mean value of 1.15±0.01 compared 0.82±0.01 in the open pond

Length-weight relationship and Fish condition factor

Nile tilapia cultured in the open and greenhouse pond had values of weight at unit length (b) of 2.24 and 3.15 respectively. The b-values of Nile tilapia cultured in the open and greenhouse ponds had a significant difference (t-test, df =1, $p>0.05$). The best-fit regression of weight (WT) on standard length (SL) by method of least squares predicted the following relationships:

i. Log W=2.2385L-1.328 or $W=1.328L^{2.2385}$ for Nile tilapia in the open pond.
ii. Log W=3.1512L-2.002 or $W=2.002L^{3.1512}$ for Nile tilapia in the greenhouse pond.

Where W=weight (g), L=Standard Length (mm)

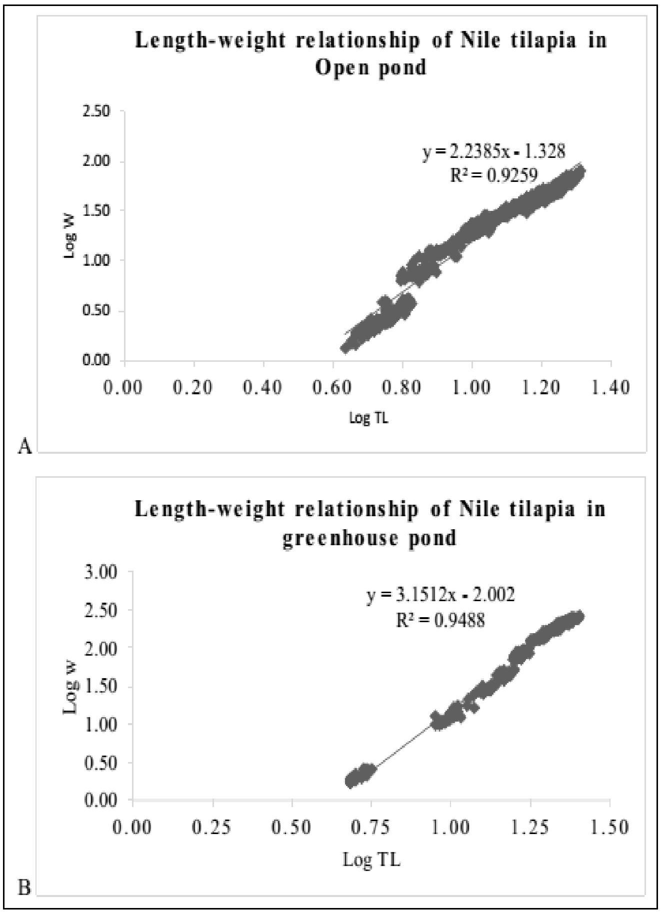

Fig 2: Length-weight relationship of Nile tilapia cultures in open pond (A) and greenhouse pond (B)

The results of condition factor of Nile tilapia cultured in the greenhouse pond had a significant difference (t-test, $p<0.05$). The calculated condition factor values were observed to be higher in the greenhouse pond than in the open pond environment. The highest value of 2.1454 was observed in greenhouse, while the lowest value of 0.8826 was observed in the open pond.

The fitted linear regression equations for logistic Length-weight relationship are presented in the Figure above

Discussion

Physico-chemical parameters

In this study, greenhouse pond had temperatures within the recommended range of 22-28 ˚C suitable for Nile tilapia [17] unlike the open pond. Higher mean temperature recorded in the greenhouse pond might be due to the '*greenhouse effect'*. During sunshine, total solar radiation received by the greenhouse cover is partly reflected, absorbed and transmitted inside the greenhouse through walls and roofs. A large portion of this transmitted radiation is absorbed by water hence increased temperature [18]. Findings from this study were in line to ones recorded in previous study [12] which recorded temperature range within 22.67-27.33 ˚C and a mean value of 24.19±0.0 2 ˚C while studying temperature in greenhouse aquaculture pond at Eldoret Kenya. Temperature results obtained in the open pond also compared with previous study [12] on earthen pond temperature dynamics and recorded mean temperature value of 20.50±0.07 ˚C

In the current research, oxygen values recorded in the greenhouse and open pond were within the recommended range of 4-8mgL^{-1} as suitable for aquaculture production [19]. The daily mean oxygen concentration recorded in the open pond was higher compared to the greenhouse pond. Higher oxygen concentration in the open pond could be resulting from mechanical aeration by wind as opposed to greenhouse pond which was sheltered hence wind effect was absent [20].

The pH ranges recorded in the two culture systems were within the recommended range of 6.7 to 9.5 as suitable for aquaculture and the ideal pH for optimal growth of fish between 7.5 and 8.5, pH above and below this could be stressful to the fish [21]. The pH values recorded in the open pond were more alkaline compared to greenhouse pond. Open pond recorded a pH range of 7.63-8.55 while greenhouse pond's pH range was 7.44-8.27. The differences in the results could be accounted for by the dilution effect of precipitation [22] on the open pond as opposed to greenhouse pond.

In the current experiment, mean daily EC recorded in the greenhouse pond (578.07±21.02µs/cm) was higher compared to that of open pond (500.15±39.81µs/cm). The differences in EC observed might be a result of dilution effect by rainfall in the open pond hence lower values as opposed to greenhouse pond [23] since both fish ponds are earthen. The EC values obtained from both ponds in this experiment were within the acceptable EC range of 100-2,000µs/cm recommended in aquaculture [24]. Similar values within the recommended EC range were obtained by previous researchers [25] working on *O. niloticus* at Kegati Aquaculture Research Station.

Ammonium, Nitrite and Nitrate

In the current experiment, the ammonium ion levels recorded were within the recommended range of below 0.5mg/L [21]. However, Mean ammonium ion concentration in the greenhouse was higher compared to the open pond. The high concentrations can be due to relatively higher temperature present in the greenhouse than in the open pond. Higher warmer temperatures favor denitrification process by the microbes which reduce NO_2^- and NO_3^- into NH_4. Findings by [26] reported that ammonium levels increase with warmer temperatures. Findings by [27] obtained similar results of concentration in the range of 20-50µgL^{-1} in fish ponds within Busia County-Kenya.

Mean nitrite levels of 0.03±0.01 and 0.02±0.01mg/L recorded in the open and greenhouse pond respectively were within the acceptable range of 0 to 1mgL^{-1} [24]. Higher values recorded in the open pond could be explained by oxidation of ammonium ions, yielding nitrite as an intermediate state [28]. Furthermore, relatively higher oxygen levels in open pond could have favoured the oxidation of ammonium into nitrites [29].

Mean nitrate levels recorded in open pond and greenhouse pond were 0.05±0.01mg/L and 0.03±0.01mg/L respectively, values which are below the recommended level of 0-4.00 mg/L [30]. The mean concentration of Nitrate in the open pond was higher compared to the greenhouse pond system. The relatively higher mean oxygen concentrations recorded in the open pond, could have accelerated the nitrification process converting nitrites into nitrates.

Soluble Reactive Phosphorus and Total Phosphorus

Results of this study indicated no significant differences in mean SRP and TP concentrations in the open pond and greenhouse pond. However, greenhouse pond recorded slightly higher SRP and TP concentrations compared to the open pond. Possible cause could be resulting from the temperature differences observed in the two systems. According to [4], temperatures accelerate the biological and chemical reduction processes releasing bound phosphate from sediments into water column.

The SRP concentrations obtained from both pond systems were higher than 2.9 to 6.0µgL^{-1} range documented by [31] in tilapia ponds in Kurdistan region of Iraq. Research at Asian Institute of Technology, carried out by [32], studying the effect of rice straw mat on water quality parameters in earthen ponds obtained TP concentrations in the range of 270 to 720µgL^{-1} values which are in line with the findings in our study.

Fish growth

Nile tilapia in the greenhouse pond gained more weight (246.74±1.96g) which was upto four-fold compared to final mean weight (57.89±2.61g) recorded for Nile tilapia in the open pond. The calculated absolute growth rate and specific growth rate were also higher in the greenhouse pond than in open pond. These can be explained by the temperatures attained which were in the recommended temperature range of 22-28 ˚C favoring the growth of tilapia. Temperature has a direct effect on fish metabolism and physiology and ultimately fish growth rate [33]. Furthermore, optimal temperature has been associated with increased fish activeness hence increases the feed intake rates and improves the food conversion efficiency [34].

According to [17], temperature range of 22-28 ˚C is recommended as suitable for growth of Nile tilapia. Studies by [35] illustrated that drastic temperature drop in any aquaculture system has a negative impact on the growth rate of fish. The greenhouse pond recorded temperatures in the range of 20.90-27.13 ˚C. The greenhouse raised water temperature by 4.84 ˚C and maintained it within the required optimal range for growth of Nile tilapia. On the other hand, open pond had temperatures in the range of 15.60-24.40 ˚C a fluctuation difference of 8.80 ˚C. Therefore, higher temperatures with a narrow range might explain the higher growth rate of Nile tilapia in the greenhouse pond than in the open pond.

Length-weight relationship and Fish condition factor

Length weight regression plots indicated that b values of Nile tilapia cultured in the greenhouse pond were closer to three (3), a growth which is termed to be isometric. On the other hand, b values recorded for Nile tilapia cultured in the open pond were below three (3), a growth which is termed as negative allometric. The b values obtained for Nile tilapia in the greenhouse pond agrees with [36] who recorded an isometric growth with b exponent value of 2.99 for Nile tilapia in earthen ponds. In the open pond, the b exponents obtained for Nile tilapia were less than 3, an indication of a negative allometric growth. The results were in line with findings of [34] who recorded a negative allometric b-exponent value of 2.01 for Nile tilapia cultured in the earthen open ponds in Kisii, Kenya.

In aquaculture, condition factor is important indicator of health and well-being of fish in relation to their culture environment. Furthermore, it is a useful tool for monitoring the feeding intensity and growth rates of fish [37]. In the current study, Nile tilapia cultured in the open and greenhouse pond recorded mean K values of 0.88 and 2.14 respectively. These results indicate that in the greenhouse pond system, fish grew in a healthy good condition than in the open pond. The differences might be attributed to temperature differences in the two environments since the physico-chemical parameters from the two pond systems did not vary significantly. Temperature greatly influences the metabolic rate of fish which has a profound effect on the food conversion ratio and eventually the condition factor.

Open pond recorded mean temperature in the range of 13.8 to 23.5 ˚C which was negatively out of the optimum performance temperature range. The greenhouse pond on the other hand recorded a temperature range of 22.3-27.5 ˚C in the recommended temperature range favoring warm water fish species. Optimum temperature range recorded in the greenhouse pond improved fish metabolism hence food conversion ratio resulting to high condition factor observed [33].

Conclusion

Current study concluded that greenhouse has a major influence on water temperature, a critical parameter for growth of warm water fish species like Nile tilapia. Mean water temperature recorded in the greenhouse pond was within the recommended temperature range. Furthermore, resultant fish weights were upto four folds in comparison to fish grown in open pond

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