9

Construction and application of greenhouse techniques for aquaculture practice in the arid zone of Nigeria

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Abstract

An experimental greenhouse was constructed at the fish pond site of Federal College of Freshwater Fisheries Technology, Baga using the freestanding design style. Air temperature, water temperature and evaporation readings were observed for two weeks. Temperature records in the greenhouse ranged between 25-27°C at 6am and 26-32°C at 6pm while atmospheric temperature was observed between 22-25°C at 6am and 24-28°C at 6pm respectively. Evaporation rates were observed to be higher in the water trough placed outside than the one placed inside the greenhouse. Water depth dropped from 39.5cm to 34.5cm (i.e. 9cm) and 39.5cm to 30.5cm (5cm) in the trough placed outside and inside the greenhouse respectively. From this experiment, water is conserved as a result of low evaporation rate and higher water temperatures are attainable in the greenhouse which is desirable in the extremely cold harmattan season in the arid zone of Nigeria.

Keywords: Aquaculture, greenhouse techniques, arid zones

Introduction

Greenhouse (also called a glass house) is a building in which plants are grown (Wikipedia, 2012; Beard, 2001) and range in size from small sheds to very large buildings. Different types of covering materials, such as glass or plastic roof and frequently glass or plastic walls are used for its construction. Greenhouse heats up because incoming visible solar radiation (for which the glass/plastic material is transparent) from the sun is absorbed by plants, soil, and other materials inside the building. Air warmed by the heat from hot interior surfaces is retained in the building by the roof and wall. The warmed structures and plants inside the greenhouse re –radiate some of their thermal energy in the infrared spectrum, to which glass is partly opaque, thereby maintaining this energy that is also trapped inside the greenhouse (Cunningham, 2000). The glass or plastic material used for a greenhouse works as a barrier to air flow, and its effect is to trap energy within the greenhouse. The air that is warmed near the ground is prevented from rising indefinitely and flowing away. Although heat loss due to thermal conduction through the glass and other building materials occurs, net energy increases as well as temperature inside the greenhouse (Olivier, 2001).

Greenhouses are used for growing crops such as plants, vegetables and flowers, but today, it is now used in aquaculture/ aquaponic practice. Commercial glass greenhouse are often high – tech production facilities for growing vegetables, flowers or other purposes. These glass greenhouses are fitted with equipment such as screening, installation, heating, cooling, lighting, and may be automatically controlled by computer. Depending upon the level of management of greenhouse, key factors which may be controlled include: temperature, light, water, fertilizer application and atmosphere. The greenhouse should be located where it gets maximum sunlight. The first choice of location is the south or southeast side of a building or shade trees. Sunlight all day is best, but morning sunlight on the east side is sufficient for plants (Wikipedia, 2012). Morning sunlight is most desirable because it allows the plants food production process to begin early. The next best sites are south east and west of major structures, where plants receive sunlight late in the day. North of major structures is the least desirable location and is good only for plants that require little light (Muijzeberg, 1980).

The extremely low temperatures during the harmattan season in Baga (which can be as low as 9°C) often result in very poor metabolic activities in fish during this period since fishes are cold blooded animals. On the other hand, high temperatures (which can be as high as 45°C) results in high evaporation rate during the heat season. Conservation of water in culture facilities becomes a dilemma. These observations inspired this study in order to find out ways to provide conducive environment for fish culture irrespective of the season. The aims of this study are to construct a model/ experimental greenhouse in the arid zone of Nigeria and to compare water evaporation rate from a receptacle in the greenhouse alongside with a similar receptacle placed outside.

Materials and Methods

The construction and study was carried out in the fish pond unit of the Federal College of Freshwater Fisheries Technology, Baga, Borno. Baga is located in the arid zone and falls within the sahel region of Nigeria. Baga lies on longitude 13° 52′ 18′E and latitude 13° 06′ 12′ W (*Collins Maps*, 2011). *Eucalyptus spp.* wood was used for stand posts on which the main frame of the greenhouse was constructed using locally available 2 x 2 plank wood. Five and a half bundles of locally available transparent PVC material was used to cover the entire frame, windows and door. The dimension of the greenhouse was 2 x 3 x 2metres (i.e. LBH – {length x breadth x height}) and the free standing style (Internet, 2012) was adopted. Two plastic troughs with circumference 150cm were filled to a depth of 39.5cm with water from the Baga intake canal of Lake Chad. One of the troughs was placed inside the greenhouse while the other was outside. Straw was spread on the floor of the greenhouse to act as insulating material. The temperature and water depth of the troughs were observed inside and outside the greenhouse daily. Temperatures were taken at 6am, 9am, 12noon, 3pm and 6pm while water depth in the troughs was recorded at 6am and 6pm daily. This exercise was carried out during the rainy season between the months of August and September. The cost of construction was also taken into consideration. Bar charts and graphs were used in presentation of the data obtained.

Results and Discussion

The daily temperature observations in and outside the greenhouse at 6am, 9am, 12noon, 3pm and 6pm are shown in Tables 1-4 and represented in Figures 1–4 respectively.

Table 1: Observed temperature inside the greenhouse.

Days	Temp. (°C)				
	6am	9 am	12 pm	3 pm	6 pm
1.	26	35	37	35	31
2.	26	30	33	35	32
3.	26	27	33	31	29
4.	25	28	32	34	28
5.	25	29	35	32	27
6.	26	28	33	35	30
7.	27	29	31	31	26
8.	26	30	33	31	30
9.	27	26	34	30	28
10.	25	27	35	32	26
11.	28	30	31	32	26
12.	26	28	30	31	28
13.	25	27	31	28	27
14.	26	27	32	33	28

Table 2: Observed temperatures outside the greenhouse.

Days	Temp. (°C)				
	6am	9 am	12 pm	3 pm	6 pm
1.	24	28	37	28	26
2.	24	26	28	31	27
3.	22	24	26	29	27
4.	22	24	27	28	24
5.	23	25	28	28	34
6.	24	26	30	32	28
7.	25	27	28	27	24
8.	24	26	31	28	24
9.	27	24	30	26	25
10.	24	27	32	27	26
11.	25	28	27	25	24
12.	23	26	28	29	27
13.	24	26	27	28	25
14.	24	25	26	25	26

Table 3: Observed water temperatures inside the greenhouse.

	Temp. (°C)				
Days	6am	9am	12 pm	3 pm	6 pm
1.	32	37	40	35	38
2.	32	34	37	39	37
3.	31	33	37	38	37
4.	32	34	36	38	37
5.	31	33	38	40	36
6.	31	32	37	40	38
7.	31	32	38	40	37
8.	31	34	38	39	37
9.	32	33	38	39	35
10.	32	33	40	39	36
11.	32	35	37	39	36
12.	31	34	38	40	37
13.	31	28	38	40	37
14.	31	32	40	41	38

Table 4: Observed water temperatures outside the greenhouse.

	Temp. (°C)				
Days	6am	9am	12 pm	3 pm	6 pm
1	28	32	38	36	35
2.	29	31	36	37	35
3.	27	28	34	36	34
4.	25	28	32	36	33
5.	27	29	36	32	34
6.	27	29	36	28	32
7.	28	30	37	38	35
8.	27	36	32	38	36
9.	30	31	37	36	32
10.	28	31	38	36	35
11.	29	31	36	37	34
12.	27	32	36	38	35
13.	28	30	37	37	35
14.	28	30	36	38	35

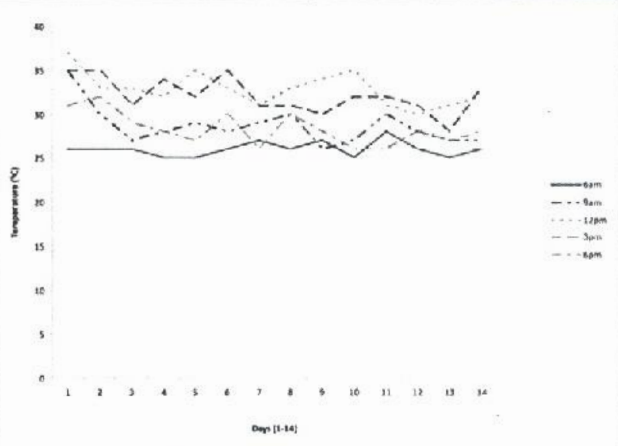


Fig. 1: Daily temperature fluctuations at 6am, 9am, 12pm, 3pm and 6pm inside the greenhouse.

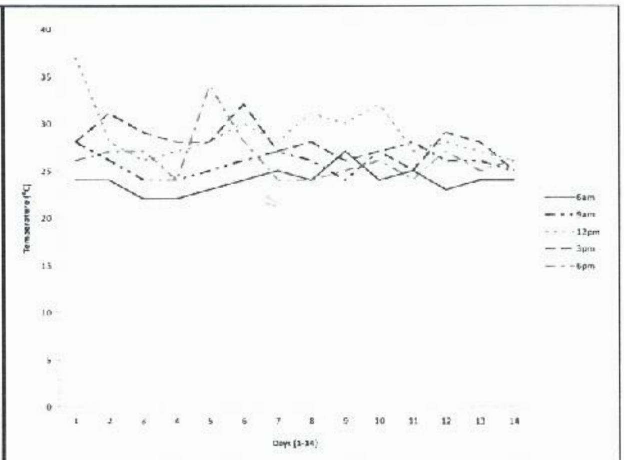


Fig. 2: Daily Temperature fluctuations at 6am, 9am, 12pm, 3pm and 6pm outside the greenhouse.

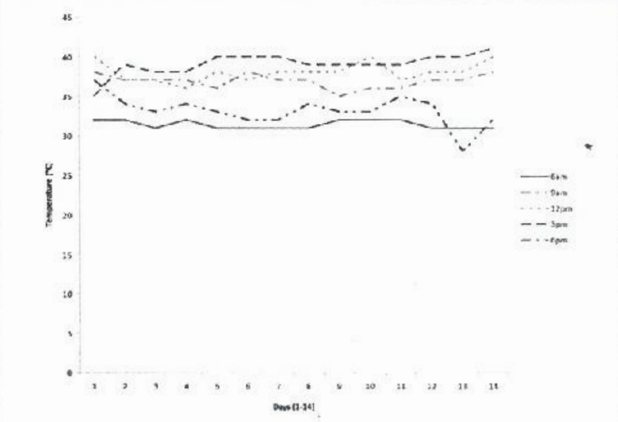


Fig. 3: Observed water temperatures at 6am, 9am, 12pm, 3pm and 6pm inside the greenhouse

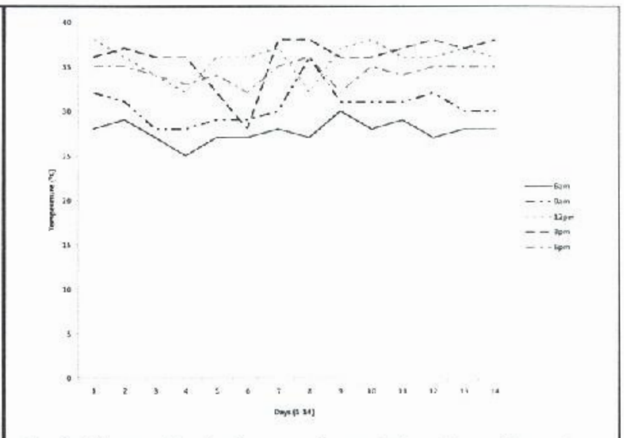


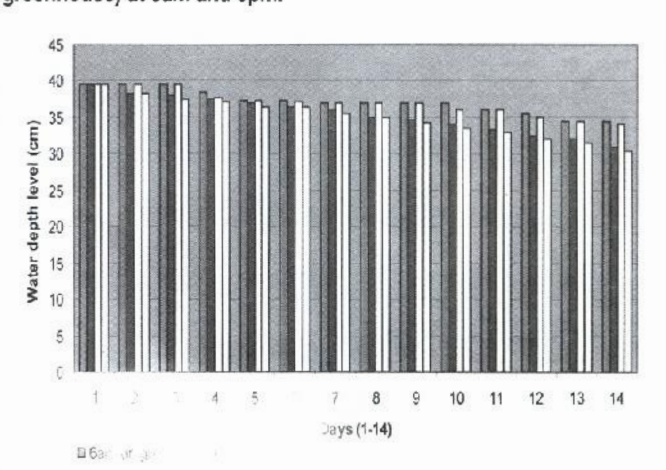
Fig. 4: Observed water temperatures at 6am, 9am, 12pm, 3pm and 6pm outside the greenhouse.

Table 5 shows the daily variations in water depth of the troughs inside and outside the greenhouse at 6am and 6pm during the period of the study. These observations are presented in Figures 5 and 6.

Table 5: Recorded water depth inside and outside the greenhouse.

	Trough inside greenhouse		Trough outside greenhouse	
Days	Water depth (cm) 6am	Water depth (cm) 6pm	Water depth (cm) 6am	Water depth (cm) 6pm
1	39.5	39.5	39.5	39.5
2	39.5	39.5	38.2	38.2
3	39.5	39.5	38	37.5
4	38.5	37.5	37.5	37.2
5	37.4	37.3	37	36.5
6	37.3	37.1	36.4	36.4
7	37	37	36	35.5
8	37	37	35	35
9	37	37	34.7	34.3
10	37	36	34	33.5
11	36	36	33.4	33
12	35.5	35	32.5	32
13	34.5	34.5	32	31.5
14	34.5	34	31	30.5

Fig. 5: Daily comparison of water depth in troughs (in and outside the greenhouse) at 6am and 6pm.



Tables 1 and 2 and Figures 1 and 2 shows the observed atmospheric temperature inside the greenhouse for two (2) consecutive weeks respectively. It was observed that the air temperature inside the greenhouse was higher than the air temperature outside the greenhouse. This was because the greenhouse traps solar radiation, heats up the greenhouse and maintains it. This was also observed and recorded by Lean (2010). Proper management of the temperature and humidity in the greenhouse is therefore a critical element for the success of the greenhouse (Lockwool, 2009).

Greenhouse temperature can be controlled by opening the ventilating opening to let out excess heat. According to Oreskes (2004) installing a thermostat ventilating system can be used to control greenhouse temperature level; typically it is quite successful and it does not rely on human control and will turn on or off automatically when the temperature gets too high or too low.

The observations recorded in Tables 3 and 4 shows the water temperature inside and outside the greenhouse. It was observed that the temperature of water inside the greenhouse was higher than the one outside the greenhouse. IPCC (2007) stated that greenhouse itself affords protection from the element and draws in heat from the sun in the warmer period. Since water has a high heat capacity, water temperature of the trough in the greenhouse does not drop exceedingly too low since the interior still remains rather warm. Figures 3 and 4 show the observed water temperatures at 6am, 9am, 12pm, 3pm and 6pm inside and outside the greenhouse for 2 weeks.

The observations recorded in Table 5 shows the water depth measurement observed in the troughs in and outside the greenhouse. It was observed that the rate of evaporation of the water in the trough outside was higher than the rate of water evaporation inside the greenhouse. This was due to direct heat from the sun resulting in direct evaporation from the water surface but the container in the greenhouse though has a higher water temperature, because there is no direct effect of heat from the sun it does not lead to excessive evaporation of the water. Figure 5 shows the variation in water depth in troughs (in and outside the greenhouse) at 6am and 6pm daily respectively for 2 weeks.

This observation of higher water temperature in the greenhouse and low evaporation rate is a desirable quality for use in fish culture practice in greenhouse especially during cold seasons with extremely low temperatures that can have adverse effects on the growth and survival of fish. Fishes could be cultured successfully in greenhouses during harmattan/winter season and growth and development will not be hindered due to the extremely low temperatures which lead to drastically reduced physiological activities (sluggish movement and cessation of feeding). The experimental greenhouse was constructed at a cost of about ₦25,000.00.

Conclusion

Research and experimental work have observed that greenhouses can be successfully and gainfully constructed using less costly materials such as polyethylene material depending on durability of the polyethylene material. Aquaculture practice is also possible in greenhouses in the arid zone and winter areas where temperatures usually drop very low. Culturing of fish can be carried out with minimal investment in construction of a greenhouse to successfully raise fish and carry out other aquacultural practices during these periods. Since fishes depend on temperature of their environment, greenhouse should be checked regularly to maintain the temperature in order to avoid over heating or cooling which will influence directly on the performance of fishes.

Baga with its extreme weather conditions experiences high temperatures of about 45°C during the heat season and extremely low temperatures of 9°C during the harmattan will benefit positively with the use of greenhouse for aquaculture creating an all year round conducive environment. A greenhouse therefore can play dual roles during these weather extremes as it will serve to check excessive evaporation rates during the heat season and also conserve temperatures during the extremely cold harmattan season.

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