Benha Journal of Applied Sciences (BJAS) **print : ISSN 2356–9751**
Vol.(2 Issue(1) Oct.(2017), 105-111 **online : ISSN 2356–976x**
http:// bjas.bu.edu.eg

Direct and Indirect Evaporative Cooling for Closed Greenhouse during the Summer Peak Hours

A.E.Newir[1], M.A.Ibrahim[1], M. A. Halawa[2], O.E. Abdellatif[3]
[1]Mechatronics Engineering Dept., Faculty of Engineering, October 6 Univ., Egypt
[2]Mechanical Engineering Dept., Faculty of Engineering, Al Azhar Univ., Egypt
[3]Mechanical Engineering Dept., Faculty of Engineering, Benha Univ., Shoubra, Egypt

Abstract

Energy saving in greenhouses is a key objective in the world, especially in the summer. So it is necessary to design cooling systems that saving energy and reach temperatures below 30 ℃ inside the greenhouse and maintaining it almost consistently to sustain the operation of the greenhouse. The objective of this study is to make a direct evaporative system (Fan –Pads) in case A and adding indirect evaporative system (cooling tower) plus fan-pads system in case Band made a comparison between them, also study the effect of each of them with respect to the outside temperature. The experiments conducted in October 6 University, 6 October city, Giza, Egypt at summer rush hours. The results was maintain the temperature variation under 30 ℃ during the day rush hours, especially in the area designated for the growth of plants inside the greenhouse.

Keywords: Greenhouse, Direct evaporative cooling, Indirect evaporative cooling.

1. Introduction

Soilless agriculture become one of the most important forms of modern agriculture because it has a positive impact on the production of crops with high quality away from the soil diseases that present the exposure of plants and crops to damage. Aquaponics system is one of the most important of these modern agriculture systems, which depends on the growth of plants and fish in the same cycle of water, so it is necessary to maintain a temperature between 27 and 30 according to the standard data from FAO [1] at most time of the year to obtain the largest production in the least time of this system. It is difficult to provide these conditions inside the greenhouse with renewable energy to ensure the sustainability of this system.

Evaporative cooling in a commercial greenhouse equipped with a pad-fan system for use during the summer period in arid countries was studied [2]. The volume flow rate through the evaporative pad was determined by the number of air changes per hour (AC/h) and estimated that 20 number of air changes were sufficient to reach tolerable conditions inside the greenhouse under dry weather conditions. The water required for evaporative cooling and absolute humidity (AH) was also determined.

Investigated the temperature and humidity gradients during summer in a rose production greenhouse equipped with a ventilated cooling-pad system and a half shaded plastic roof [3]. Three portable instruments used for measurements in the total area (50 m *60 m). The cooling performance was achieved up to 80% and the temperature of the greenhouse was lowered by 10℃ than the outside air.

Conducted theoretical and experimental studies in a 24 m^2 greenhouse with a fan-pad evaporative cooling system of (3*1.15)m^2 area in the west wall and two fans in the east wall are shown in [4]. Greenhouse air temperature was reported 4–5 ℃ lower as compared to the outside conditions in the rectangular zone (zone II) but in the triangle zone (zone I) found the temperature was highest than the outside temperature with almost 5℃ in the day rush hours. Fan-pad cooling parameters such as length of the greenhouse, air mass flow rate, height of the cooling pad was also performed.

In another application liquid desiccation with solar regeneration as a means of lowering the temperature in evaporative-cooled greenhouse was studied by Davies (2005). The cooling was assisted by using the regenerator to partially shade the greenhouse. The heat of desiccation was transferred and rejected at the outlet of the greenhouse. The cycle was analyzed and results given for the climate of the Gulf, based on weather data from Abu Dhabi. The cycle was compared with conventional evaporative cooling and found that the proposed system lowered summers maximum temperatures by 5 C. [5]

Experiments have been conducted in hot summer conditions at Solar Energy Park, New Delhi, India for empty greenhouse [6]. Statistical analysis has been carried out to validate the agreement of experimental observations with predicted values. It is found that the use of evaporative cooling with a thermal curtain reduces the temperature of greenhouse by 5°C and 8°C in the second zone of greenhouse-1 and 2 in comparison to greenhouse without curtain in May, However, the temperature inside the greenhouse was higher than the outside temperature except the temperature of rectangular zone in greenhouse 1 the greenhouse temperature was equal to the outside temperature[7].

studied the efficiency of fan-pad cooling system in greenhouse by building up of internal greenhouse temperature map. The results reveal that the drops in temperatures are found to be 10-12 °C at 2 PM only.

Considerable differences are recorded between the temperatures in center of the pad and in front of the fans at the center of the greenhouse (13℃ at right in front, 8℃ at middle of the pad and 7 °C in front of the fan).

The purpose of this study was to evaluate the performance of direct evaporative cooling (fan-pad system) only and when adding indirect evaporative system (cooling tower) to the direct evaporative system in greenhouses. Reach to the suitable temperature for the Aquaponics System is the main objective of this study.

2. Experimental Setup

The experiments located at October 6 University, Giza, Egypt (longitude 29.98^o, latitude 30.95^o) and conducted During peak sunshine hours between 10:00 AM and 5:00 PM. The greenhouse is inclined roof type even span, which is made of rectangular iron pipes and Polycarbonate sheets covering material. The greenhouse with an effective floor 3.6x2.4 m^2 with central height and height of the walls were 2.4 and 1.8 m, respectively.

A fan of 350 mm sweep diameter and 1360 rpm with a rated air volume flow rate of 3200 m^3/h was provided on the south wall of the greenhouse for the forced convection experiments. Evaporative cooling system Corrugated cellulose paper pads located in the northern wall at a height of 0.9 m, length 0.55 m and full width of the greenhouse 2.4 m.

Depending on climatic conditions, many buildings can use indirect/direct evaporative air conditioning to provide comfort cooling. Indirect/direct systems achieve a 40 to 50% energy savings in moderate humidity zones (Foster and Dijkstra 1996) [8].

It is often desirable to combine the effects of direct and indirect evaporative processes (indirect/direct). The first stage (indirect) sensibly cools the air, thereby lowering its wet-bulb temperature, and passes it through the second stage (direct) where it is evaporative cooled further. [9](ASHRAE, 2012)

In case A water was pumped upwards to the cooling pads and then collected in the water tank for reuse. In case B water pumped to cooling tower to decrease the water temperature which used in cooling pads then flows to the water tank for reuse.

In both cases for measuring temperature used 46 digital temperature sensor (DS18B20) with temperatures range from -55°C to +125°C and ±0.5°C Accuracy from -10°C to +85°C, DHT22 relative humidity sensor with accuracy of 2-5% on the full scale range of 0-100% of relative humidity.

Fig (3) show the distribution of the horizontal and vertical sensors created to measure the temperature, horizontal lines was put on height 1.6 m when the vertical lines centered at the meddle at 1.2 m, both of vertical and horizontal lines distributed in the quarter, meddle and three quarter sections inside the greenhouse.

Greenhouse walls temperature measured by 7 (DS18B20) temperature sensor one for each wall and two for the even span roof. In each horizontal line put 5 (DS18B20) the distance between each of them 0.4 m and for the vertical line used 7 temperature sensors distributed in two parts, used 4 sensors for the bottom part the distance between each of the 0.4 m and the top part consists of 3 sensors with 0.2 m intervals between them. Used also two (DS18B20) temperature sensor to measure outside and inside temperature. Used two DHT22 to measure relative humidity inside and outside the greenhouse.

The experiments were carried out on 30 August for case A and 1 September for case B. Weather temperature trend for October 6 City during the experimental study, for case A the high and low temperature was 33°C and 23°C respectively and for case B was 33°C and 24°C. [10]

Fig (4).a shows the outside and inside humidity for case A and B. the difference between outside relative humidity for case A and case B can have predicted because the difference between the outside temperature shown in fig(4.b),the average outside relative humidity difference for case A was highest than case B with almost 6.8%. On the other hand, can see the difference in the average outside temperature figure (4.b) of case B was highest than case A with 2℃.

The operation of cooling systems of the greenhouse started at 9:30 AM. So, there was no effect on the operation of cooling systems at 10 AM. Note the average relative humidity difference between the inside and outside the greenhouse for case A and B, this difference was almost 12% for each case due to the operation of cooling systems. In case B in spite of the increase the outside temperature, the average difference in relative humidity was maintained and this is due to the operation of cooling tower. Maximum outside temperature was at 11 AM and 2 PM in case A and case B also.

Fig (5)show the temperature variation inside the greenhouse for horizontal and vertical line 1 at the summer season rush hours. At 10 AM temperature distribution in the vertical and horizontal line of case A was highest than at 11 AM due to the effect of operating cooling system but for case B the temperature distribution was almost equal, indicate that the operation of cooling tower plus fan-pads system can maintain temperature stability during working hours quickly. Can predict in the horizontal line 1 the effect of sun position at 10 and 11 AM, where sun at the east so the temperature on the east point at 2.4 m in the horizontal line was highest than the temperature at the west point in 0 m, note that this difference changes over time to become the lowest temperature difference between the eastern side and the western side of the greenhouse at 3 PM.

Reduction in temperature inside the greenhouse with regard to the outside temperature was observed in vertical line 1 for case A and B especially tell the point at head 1.2 m, the average temperature difference tell this head between the outside temperature and the inside temperature was reduced in case A with almost 7℃ and 9.23℃ for case B. which the maximum temperature difference was at 11 AM and 2 PM in both cases and this difference was 8℃ at 11 AM and 9℃ at 2 PM for case A, and 12.7℃ at 11 AM and 11.6℃ at 2 PM for case B.

It was found that temperature variation in the vertical line 2 up to a height of about 1.6 m were less than 30℃, the average difference between the outside and inside temperature in the case B was 9.33℃. The greatest difference between the outside and inside temperature at 11 AM and 2 PM and it was 13℃ and 11℃ respectively.

The temperature variation in horizontal line 3 in fig (7) can predict the temperature variation was raise up than the temperature variation in horizontal line 1 and 2 due to the effect of fans for nearness to line 3 and reducing the effect of cooling pads. Shortage of the greenhouse effect can predict in the vertical line 3 than other vertical lines, the difference between the temperature near the ground service located at 0 m and the highest point at 2.4m was almost 7 ℃.

The temperature inside the greenhouse did not exceed 30 ℃ during the peak hours of the day in the first section until height 1.2m and in the second section up to the height of 1.6m, in the third section distributed the effect of greenhouse effect to rise the temperature in the bottom and lower the temperature at the top and temperature variation range become between 30 ℃ and 35 ℃ in the vertical line 3.

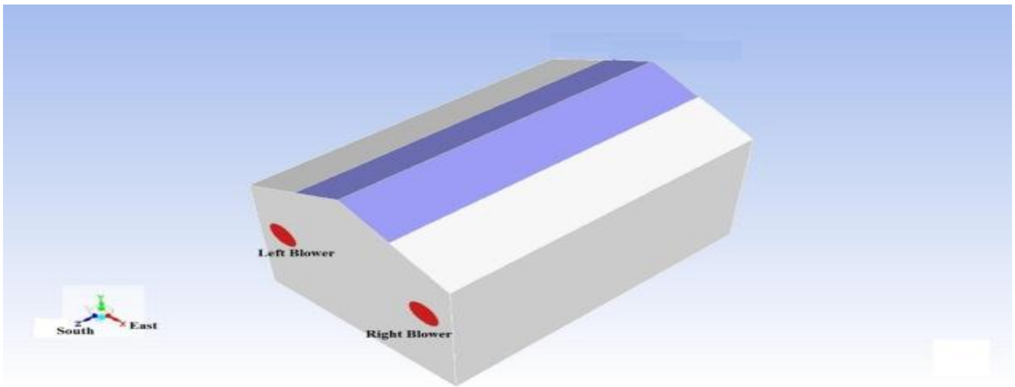


Fig (1) Layout of the greenhouse

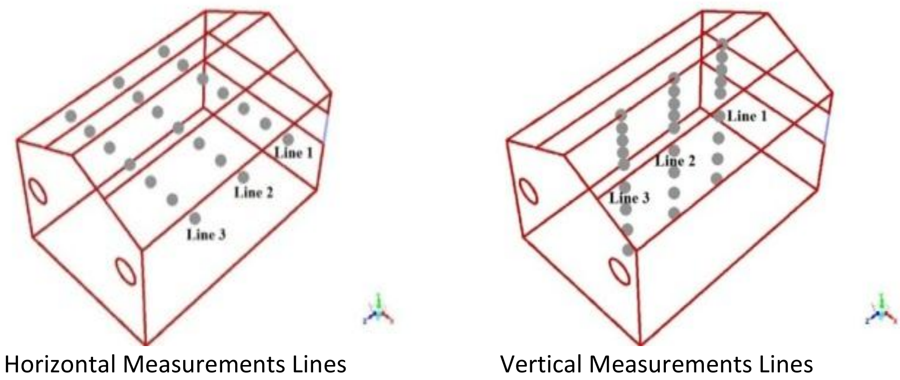


Fig (2) Horizontal and Vertical Measurements Lines

3. Results and discussion

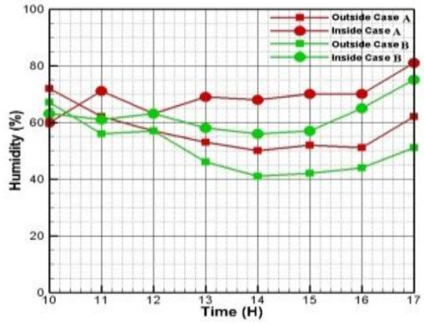


Fig (3a)

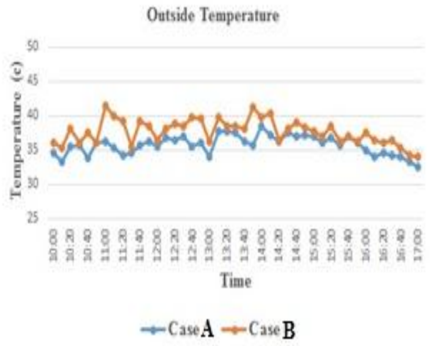


Fig (3b)

Fig (3) a)Outside and inside humidity, b)outside temperature for case A and case B

Horizontal line 1 **Vertical line 1**

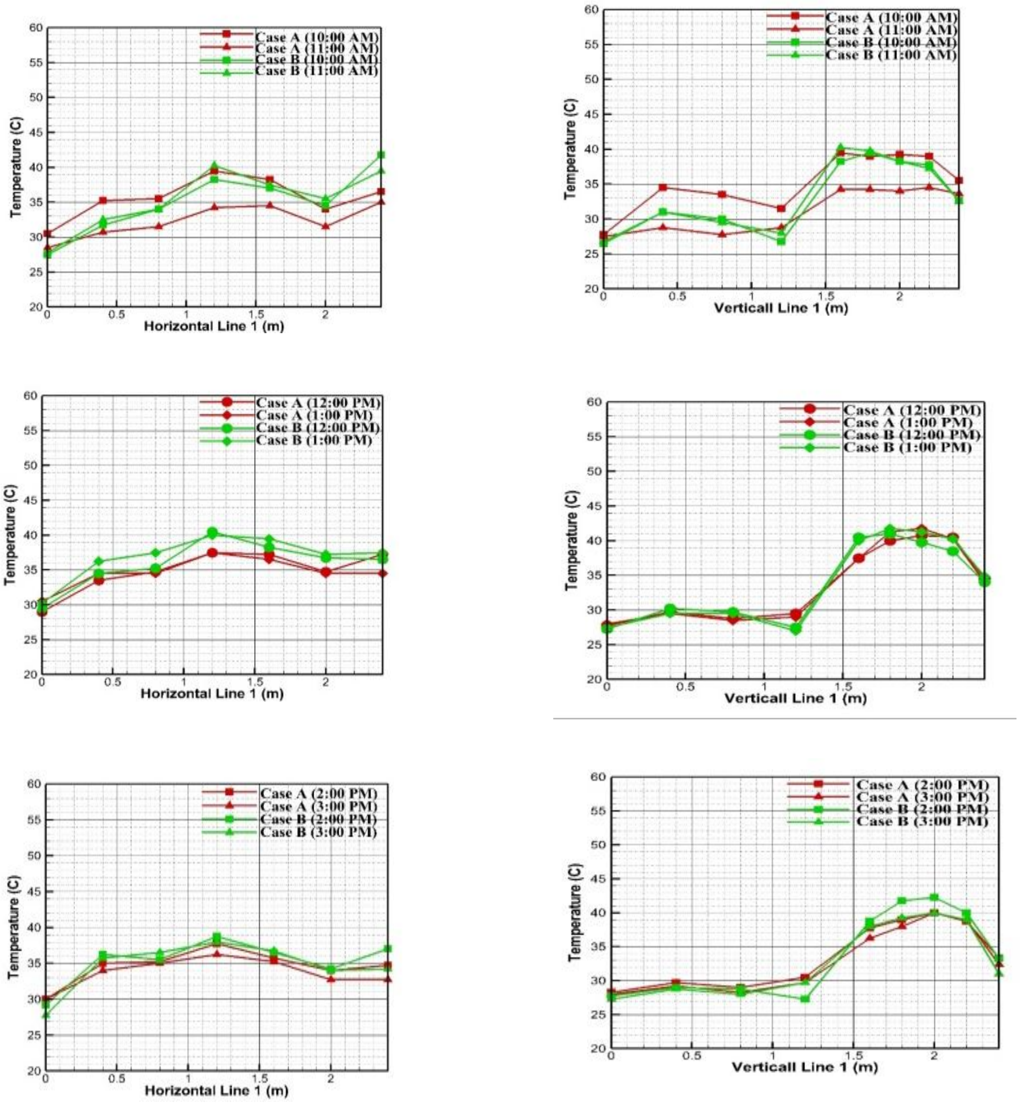
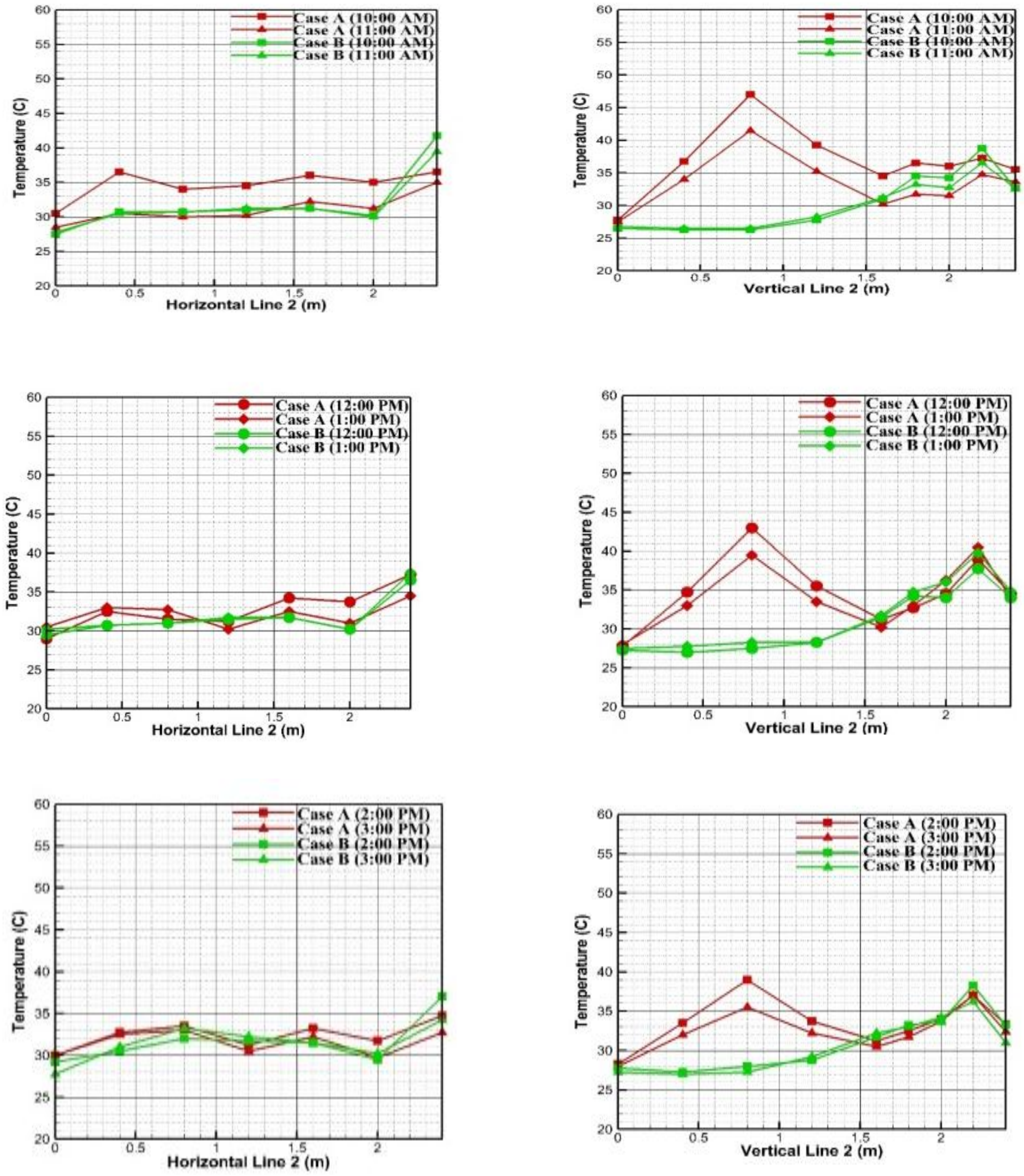


Fig (2) Temperature variation for case 1 and case 2 at horizontal line 1 (Y=1.6m and Z=0.9m) and vertical line 1 (X=1.2m and Z=0.9m).

Horizontal line 2 **Vertical line 2**



Fig(3) Temperature variation for case 1 and case 2 at horizontal line 2 (Y=1.6m and Z=1.8m) and vertical line 2 (X=1.2m and Z=1.8m).

4. Conclusion

The performance of direct evaporative cooling (Fan- Pads) system was acceptable to cooling the greenhouse and reach to good temperature distribution (not exceed 30℃) inside the greenhouse.

Using direct evaporative cooling can maintain constant temperature during day peak hours of summer season.

It is correct to depend on the operation of cooling tower with the fan-pads system for quick access tothe required temperature distribution and then depend on fan-pads system only.

Found highest temperature difference between the outside temperature and inside temperature for case A or case B when the outside temperature was in high values.

Little effect for adding cooling tower to the fan- pads system in this study.

Horizontal line 3 **Vertical line 3**

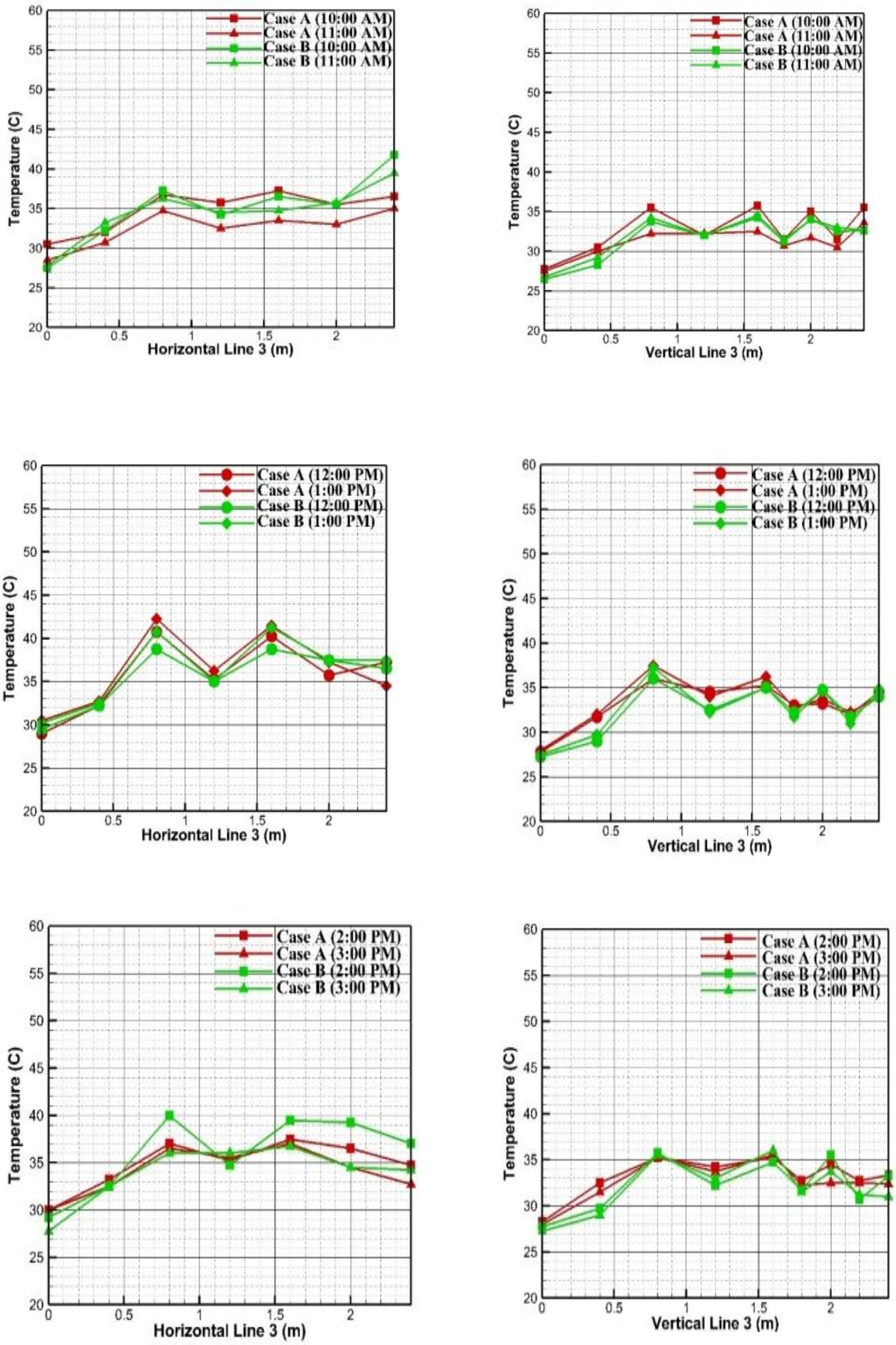


Fig (4) Temperature variation for case 1 and case 2 at horizontal line 3 (Y=1.6m and Z=2.7m) and vertical line 3 (X=1.2m and Z=2.7m).

References

[1] FAO, Small-scale aquaponic food production, Rome: Food and Agriculture Organization of the United Nations, 2014.

[2] K. Jamal, "Greenhouse cooling in hot countries," Energy, vol. 19, pp. 1187-1192, 1994.

[3] C.B.T. J.A. Kittas, "Greenhouse evaporative cooling: measurement and data analysis," Transactions of the ASAE, vol. 44(3), p.p 683–689, 2001.

[4] G. T. D. Jain, "Modeling and optimal design of evaporative cooling system in controlled environment greenhouse," Energy Conversion and Management , vol. 43(1), p.p 2235–2250, 2002.

[5] P.Davies, "A solar cooling system for greenhouse food production in hot climates," Solar Energy , vol. 79, pp. 661–668, 2005.

[6] G. T. M. S. Ashish Shukla, "Experimental study of effect of an inner thermal curtain in evaporative cooling system of a cascade greenhouse," Solar Energy , vol. 82, pp. 61–72, 2008.

[7] A.A.K. B. a. T. A. Hasan Oz, "The efficiency of fan-pad cooling system in greenhouse and building up of internal greenhouse temperature map," African Journal of Biotechnology, vol.8 (20), pp. 5436-5444, 2009.

[8] R.a.E.D. Foster, "Evaporative air-conditioning fundamentals: Environmental and economic benefits worldwide.," in Refrigeration Science and Technology Proceedings, Aarhus, Denmark, International Institute of Refrigeration, Danish Technological Institute, Danish Refrigeration Association, 1996, pp. 101-110.

[9] ASHRAE, ASHRAE Handbook—HVAC Applications, USA: ASHRAE, 2015.

[10] "msn.weather," 2016. [Online]. Available: http://www.msn.com/en-us/weather/today/6th-of-October-City,Sixth-Of-October,Egypt/we-city 29.94,30.91?q=6th-of-october-city-sixth-of-october&form=PRWLAS&iso=EG.