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DETERMINATION OF EFFECTS OF OUTDOOR RELATIVE HUMIDITY ON FAN PAD COOLING EFFECTS IN GREENHOUSES

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Summary

Greenhouses are agricultural buildings where production takes place throughout the year. In greenhouse cultivation, the objective is to ensure economically highest yield by means of adjusting the greenhouse indoor climatic conditions. During summer, cooling is needed in order to prevent overheating in greenhouse. The cooling in greenhouses is carried out via fan pad cooling systems. Hereby study aims at determining the effects of highest and lowest local humidity on indoor temperature changes, through detection of the influence of outdoor relative humidity on the system efficiency and cooling rates. The research is realised in the 24 m long, 10 m wide glasshouse in the city of Isparta. It is found out that temperature reduction values in greenhouse are highly influenced by the local highest and lowest relative humidity. According to the outcomes of the study, in a day when the outdoor relative humidity is low, temperature level rises around 6-7^{o}C compared to a day with higher humidity; therefore, the outdoor relative humidity comes up as a significant parameter for improving system efficiency. It is concluded that the most suitable hours for starting the system is 9.00-10.00 a.m., when the temperature begins to increase, for a more cooling efficiency.

Key words: cooling efficiency, fan pad, greenhouse, Isparta, outdoor relative humidity

INTRODUCTION

Climatization is the process of automatically controlling the due atmospheric environment for the comfort of man and animals, as well as cultivation of plants. In practice, it means to heat, cool, humidification or dehumidification the air for adjusting the ambience. In plant cultivation, greenhouses are agricultural buildings where production takes place throughout the year, by means of controlling atmospheric conditions. The objective in greenhouse cultivation is to ensure economically highest yield by providing the optimum environmental conditions and cultivation ambience for growth and development of plants, when the outdoor climatic conditions are not suitable for cultivation. The most important factors to be controlled in a well-planned greenhouse are ventilation, heating, cooling and lighting (Ones, 1986; Arıcı, 1999; Cemek et al., 2006).

During summer, cooling is needed in order to prevent overheating in greenhouse (Öztürk and Başçetinçelik, 2002). In greenhouses that are especially active in summer, the indoor temperature can be 5-10^{o}C higher than outdoor temperature due to the effects of solar rays. This may reduce or stop the assimilation by plants (Yüksel, 2000). Such inconveniences decrease the maximum output in greenhouse cultivation, and the expected incomes cannot be attained. Direct and indirect cooling applications are used in greenhouses for cooling. The direct cooling systems are implemented as fan pad system, fogging and water spraying system (Öztürk and Başçetinçelik, 2002; Yüksel, 2000; Yağcıoğlu, 2005).

Fan pad (humidification) cooling is a method of decreasing the temperature by means of water vapour in the air. Once the water is evaporated, its temperature decreases, due to loss of energy. For evaporative cooling systems, 2 air temperatures, namely, dry air and wet air temperatures are present. Dry air temperature signifies the temperature in outdoor conditions. The wet air temperature is expressed via the rise of humidity in dry air (Bucklin et al., 1993). According to certain experts, fan pad cooling can ensure efficiency through direct humidification only in locations where the average relative humidity is lower than 40% in midday in June. However, for some other researchers, this method can ensure efficient cooling in locations where the wet thermometer temperature is at most 24^{o}C and the dry thermometer temperature exceeds 32^{o}C (Ozbugan, 1995).

The specialists indicate that in the duly desinged systems, fan pad cooling system has an efficiency rate of 80-85% for ensuring indoor temperature 10-15^{o}C lower than outdoor temperature (Yağcıoğlu, 2005; Jain and Tiwari, 2002; Kittas et al., 2003; Davies, 2005; Fuchs et al., 2006).

Outdoor relative humidity is an important benchmark for determining the efficiency of cooling in fan pad system. Lower humidity in the location means higher efficiency of fan pad system (Bucklin et al., 1993).

Hereby study aims at determining the effects of highest and lowest local humidity on indoor temperature changes, through detection of the influence of outdoor relative humidity on the system efficiency and cooling rates. Unlike the Antalya region where greenhouse cultivation is common, Isparta is climatically convenient for our study thanks to lower outdoor relative humidity.

MATERIALS AND METHODS

Hereby research is realised in the 24 m long, 10 m wide glasshouse in the city of Isparta. The exact location of greenhouse is latitude 37° 50' N and longitude 30° 32' E. The greenhouse is built as a block, gable greenhouse and covered with monolayer of glass (Figure 1). The pads and fans are installed perpendicularly to the short axis. The roof has automatic air conditioning; natural ventilation is ensured by means of ventilation windows when fan pad system is off. Greenhouse comprises 3 paperboard pads of 2.5x1.6 m, and 2 fans of 0.55 kW and 1700 RPM.

The temperature values in greenhouse are recorded by HOBO sensor and recorder device. To that end, 9 HOBO devices are installed in the greenhouse and the temperature is recorded in 30-minute intervals. Outdoor temperature and humidity is assessed in consideration of the records from meteorological station located near the greenhouse.

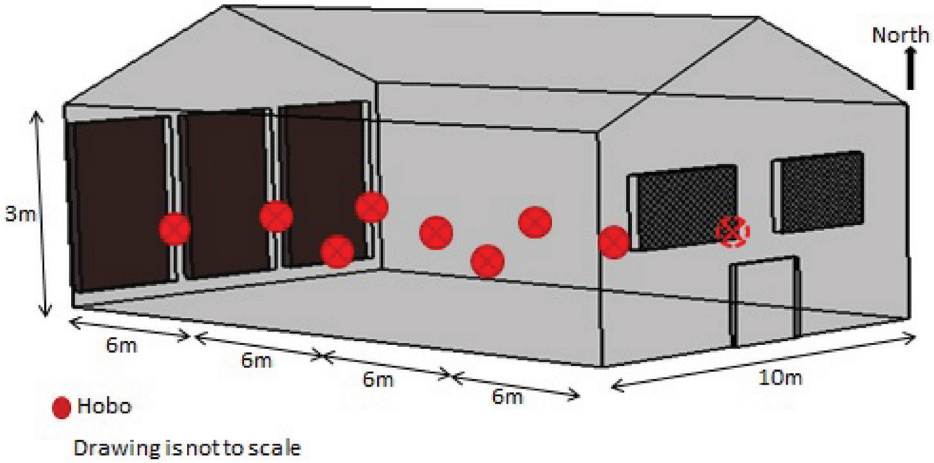

Figure 1. Size of the greenhouse and the distribution of sensors in the greenhouse

The results of measurements are processed in MS Excel 2010, and the consequences are shown in charts.

The study analyses the importance control of differences between indoor and outdoor temperature by means of paired t tests, comparing the days with highest and lowest detected outdoor relative humidity. The presence of linear relationship between the characteristics is explained via Pearson correlation coefficient (Kocabaş et al., 2013).

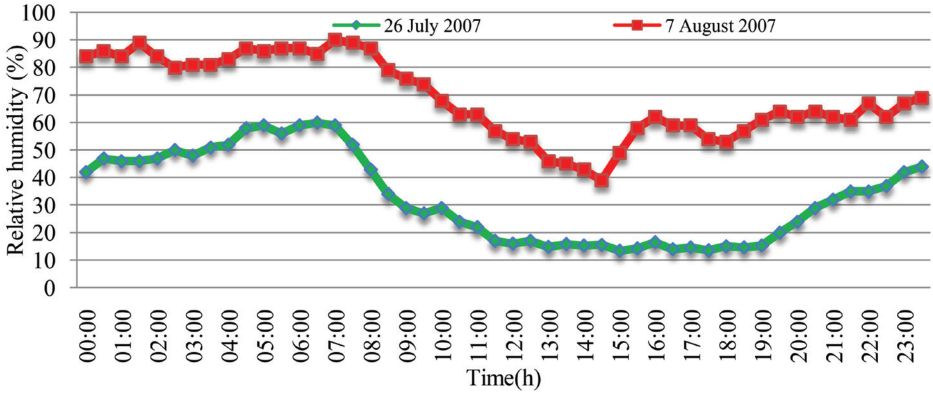

Figure 2. Hourly change of highest and lowest outdoor relative humidity values

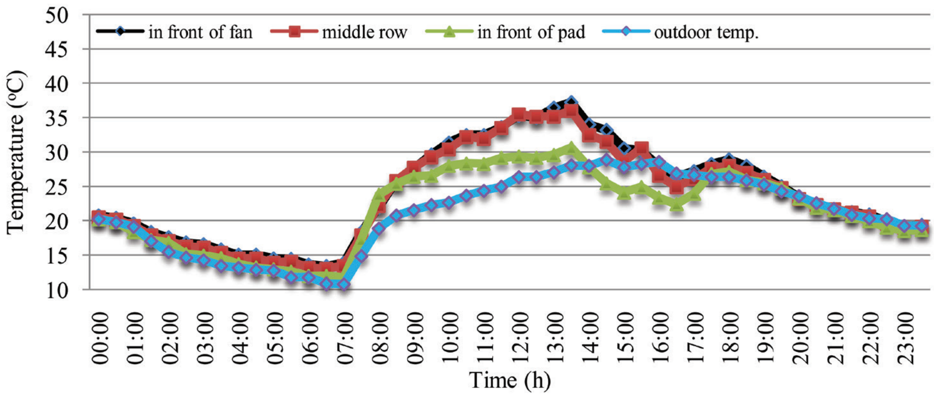

Figure 3. Hourly temperature changes in the greenhouse on 7 August 2007

RESULTS

The study was carried out between July and September 2007. The system ran during the hours when solar rays are perpendicular to earth ($12:^{00}$-$17:^{00}$), in order to ensure cooling effect. The collected data were analysed, and relevant comparisons were made pursuant to highest and lowest outdoor relative humidity values detected throughout the research. According to the assessment of values, the highest outdoor relative humidity was observed on 7 August 2007, while the lowest value was recorded on 26 July 2007 (Figure 2).

In the abovementioned days, the recorded temperatures are shown as the average of 3 measurement values: in front of the fan, middle row, and in front of the pad (Figure 3, 4).

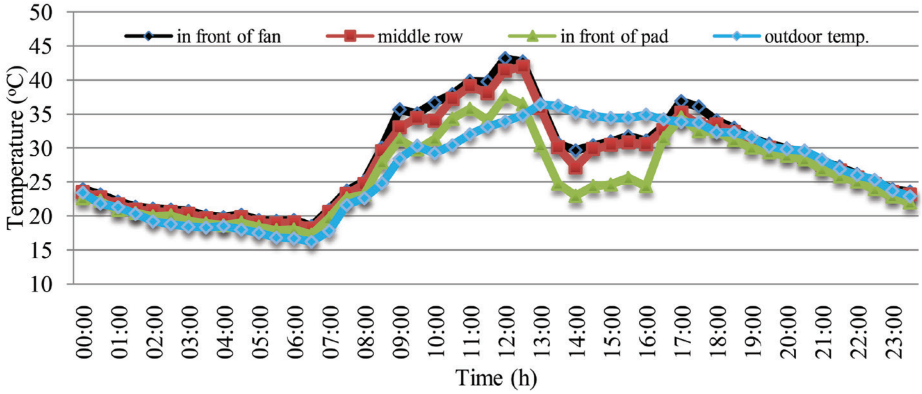

Figure 4. Hourly temperature changes in the greenhouse on 26 July 2007

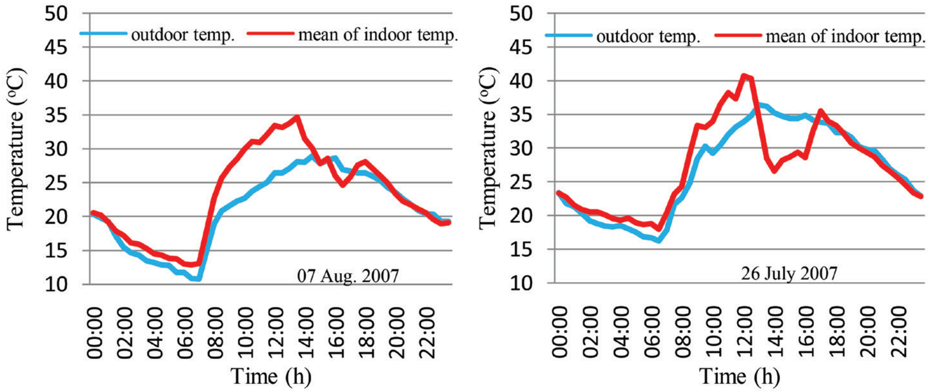

Figure 5. Hourly changes in mean indoor and outdoor temperature values

On the days with lowest and highest relative humidity values, an analysis on the average temperature of all points in the greenhouse show that the difference between indoor and outdoor temperatures are not statistically meaningful on July 26, when the relative humidity is low; however, on August 7, when the relative humidity is high, the difference is significant in statistical terms (P<0.01) (Table 1). According to calculations on detected differences, the difference between daily average indoor and outdoor temperatures yielded following results: On the days with low humidity, the total of temperature differences is 15^{o}C and the average indoor temperature is lower than average outdoor temperature; while on the days with high humidity, the total difference of temperatures attained 100^{o}C and average indoor temperature came close to average outdoor temperature (Figure 5).

In the light of obtained data, the total difference between indoor and outdoor temperatures is almost 7 times higher on the day with low outdoor relative humidity, compared to that with high relative humidity.

Table 1. Determination of importance control of indoor and outdoor temperatures

N		26 July 2007			7 August2007		
		Mean	StDev	SE Mean	Mean	StDev	SE Mean
Outdoor Temp. (^{o}C)	48	26,894	6,609	0,954	21,096	5,558	0,802
Indoor Temp. (^{o}C)	48	27,200	6,353	0,917	23,183	6,514	0,940
Difference	48	-0,307	3,495	0,504	-2,087	2,742	0,396

According to outdoor relative humidity values, it is concluded that there is a negative and statistically meaningful relationship between indoor and outdoor temperature values in both days (p<0,01). That is, temperature decreases when humidity rises (Table 2).

DISCUSSION

On August 7, when the highest outdoor relative humidity was recorded in the region, the indoor temperature began to decrease upon starting of system. The levels in middle row and in front of fan approached outdoor temperature values, while the fall of temperature in front of the pad is recorder 5^{o}C lower compared to outdoor temperature (Figure 3). The difference between outdoor and indoor temperature began to rise as of morning hours, and hit the top at noon hours. In order to preserve the optimum temperature needed by the plants, the system has to be started as of the hours when indoor temperature rapidly rises, namely as of 10 a.m. (Öz, 2007). The researchers claim that greenhouse indoor temperature can be decreased by 5-10^{o}C compared to outdoor temperature via efficient running of fan pad cooling system (Dağtekin and Yıldız, 1996; Uğurlu and Kara, 2000; Kocatürk, 2007).

On July 26, when the lowest outdoor relative humidity was recorded, the temperature values in front of the fan and middle row were 5-6°C lower than outdoor temperature; moreover, the difference increases up to 12°C in front of the pad (Figure 4). The principal condition for effective usage of evaporative cooling systems is low relative humidity in the region (Koç and Koç, 2008). In the regions with low relative humidity values, the fan pad cooling system can decrease the outdoor temperature by 6-12°C (Öztürk and Başçetinçelik, 2002).

The lower initial relative humidity of outdoor air and the higher dryness of air mean that it can absorb more water via evaporation in order to attain saturation point; therefore, the apparent temperature will fall even more, and this will enhance cooling efficiency (Yağcıoğlu et al., 2006).

Table 2. Relationship between humidity and temperature values

Days	7 Aug. Outdoor Temp. (°C)	7Aug. Indoor Temp. (°C)	26 July Outdoor Temp. (°C)	26 July Indoor Temp. (°C)	26 July Outdoor Relative Hum. (%)
7Aug. Indoor Temp. (°C)	*0,909 **0,000				
26 July Outdoor Temp. (°C)	0,978 0,000	0,929 0,000			
26 July Indoor Temp. (°C)	0,806 0,000	0,889 0,000	0,855 0,000		
26 July Outdoor Relative Hum. (%)	-0,976 0,000	-0,910 0,000	-0,983 0,000	-0,854 0,000	
7 Aug. Outdoor Relative Hum. (%)	-0,889 0,000	-0,818 0,000	-0,913 0,000	-0,698 0,000	0,898 0,000

*Pearson correlation
**P-Value

CONCLUSIONS

According to the present study on determination of cooling effect by fan pad system in greenhouses, it is concluded that it is an important factor regarding temperature reduction values in greenhouses when the relative humidity is both lowest and highest in the region. Since the values are 6-7°C lower on the day with low outdoor relative humidity, the study reveals that outdoor relative humidity is a significant parameter for enhancing system efficiency.

It is also affirmed that the cooling will be most effective in case the system is started at 9 to 10 a.m., when the temperature begins to rise.

Consequently, by means of the fan pad cooling systems duly installed in greenhouses, the cultivators can be provided with a general opinion prior to cultivation, regarding cultivation time and greenhouse indoor temperature fall, on the basis of relative humidity values in summer when greenhouse activities continue.

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