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Determining of Some Climatic Parameters with CFD in Naturally Ventilated Greenhouses

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Abstract

In this study, the comparison of measured some inner climatic factors with simulated values for cultivation of single greenhouses located North-East direction located in Western Mediterranean Agricultural Research Institute in Antalya, Turkey, and determination of the most suitable windows openness degree during 15th-19th August 2011 was aimed. For each of the gable roofed single glasshouse has the same structural and physical features. Some of the inner and outer climatic parameters were measured by locating temperature, relative humidity and velocity sensors with data loggers in 8 different points, 7 different points inside the greenhouse and one outside. Afterwards, greenhouses used were drawn in one to one properties using SolidWorks package software which is working by means of Computational Fluid Dynamics (CFD) method. The climatic conditions inside greenhouses were simulated by using limit values of temperature, humidity and wind speed measured and recorded in the ambient conditions and some structural and physical properties of greenhouses. The equation of “coefficient residual mass” was used as compliance level between the measured and simulated values to determine the most suitable combination.

In conclusion, the large similarities between the measured and simulated values and the most suitable combination in terms of cultivation was detected in number 2 greenhouse (90° window openness and 0,10 m plant height) with 95,1% compliance level. Therefore, CFD software can be used with a high success to determine the most accurate combination for cultivation.

Keywords: Greenhouse, CFD, temperature, humidity, wind speed, structure properties.

1. Introduction

The main factors which characterize and influence the greenhouse environment are light, humidity, air temperature, carbon dioxide concentration and ventilation rate.

Ventilation is the main control method of the greenhouse's high temperatures. Natural ventilation is mostly used nowadays since it requires less energy, equipment and power than other forms of ventilation. The performance of ventilation plays an important role to the production, affecting not only the environmental conditions of the greenhouse, but the qualitative and quantitative properties of the crop product as well [1].

Recent progress in computer performance and developments in flow modeling using computational fluid dynamics (CFD) provide a new opportunity to analyze the heterogeneity of the climate and to predict the ventilation rates in greenhouses. The principle of this technique is based on the resolution of transport equations in closed [2, 3] and ventilated [4] greenhouses. The CFD approach may provide a better understanding of the ventilation process for a wide range of greenhouse shapes, vent combination and boundary conditions and can help engineers and greenhouse manufacturers to improve greenhouse control and design.

The aim of this study is to compare the measured some climate parameters inside the greenhouse with the simulated values using Computational Fluid Dynamics (CFD) in a naturally ventilated, gable-roofed single glass greenhouses located North-South direction, having different window spans such as 45° and 90°. Additionally, effects of the degree of window openness on ventilation was examined.

2. Materials and methods

In this study, it was used the greenhouses located in West Mediterranean Agricultural Research Institute at the Aksu district of the Antalya province in Turkey (37° 47' N altitude and 31° 4' W latitude) on the east of Antalya as a material. The properties of greenhouses used as a material were given in Table 1.

Table 1. The properties of greenhouses used as a material

Greenhouse name	Greenhouse type	Cover type	Dimensions (m)			Window opennes	Plant height (m)	Direction of greenhouse
			W	L	H			
Number 1	Gable roofed	Glass	12.0	45.0	1.90	90°	1.50	N-S
Number 2	Gable roofed	Glass	12.0	45.0	1.90	90°	0.10	N-S
Number 3	Gable roofed	Glass	12.0	45.0	1.90	45°	1.50	N-S
Number 4	Gable roofed	Glass	12.0	45.0	1.90	45°	0.10	N-S

In the study, it was measured inside and outside climate values by locating temperature, relative humidity and wind speed sensors which were located 7 different point inside the greenhouse and one point outside of greenhouse for each greenhouse which was given in Table 1.

Measurement values were recorded at 2:00 p.m. for each greenhouse by using temperature, relative humidity and wind speed sensors located inside the greenhouse. Measurements were recorded for 4 different situations that window openness degree are 45° and 90°, plant height are 1.50 m and 0.10 m, greenhouse direction is North-South.

Then, SolidWorks 2011 package program was used to create in computer environment of greenhouses in the same dimensions by means of Computational Fluid Dynamics (CFD) method to simulate of the distribution of air temperature, relative humidity and wind speed.

It was simulated air temperature, relative humidity and wind speed values inside the greenhouses by defining the air temperature, relative humidity and wind speed values measured and recorded in outside conditions and some physical and structural properties.

The most suitable combination was determined by looking significance levels between measured and simulated values. It was used the equation below to determine significance level between values [5].

$$CRM = \frac{\sum_{i=1}^{n} O_i - \sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} O_i} * 100$$

P_i= Predicted values,
O_i= Observed values,
n= Number of samples

3. Result and discussion

For each greenhouse, significance levels obtained from calculation and screenshots belong to temperature, relative humidity and wind speed obtained from simulations were given below.

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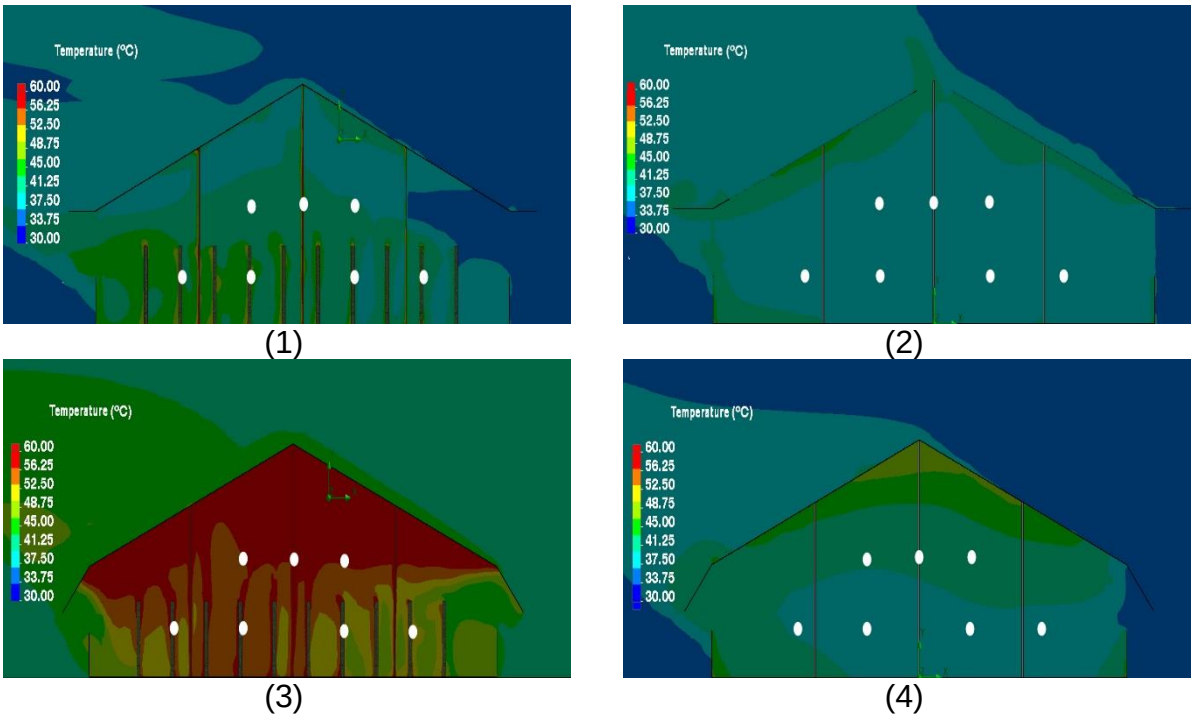

Figure 1. Simulated temperature values for number 1,2,3,4 greenhouses

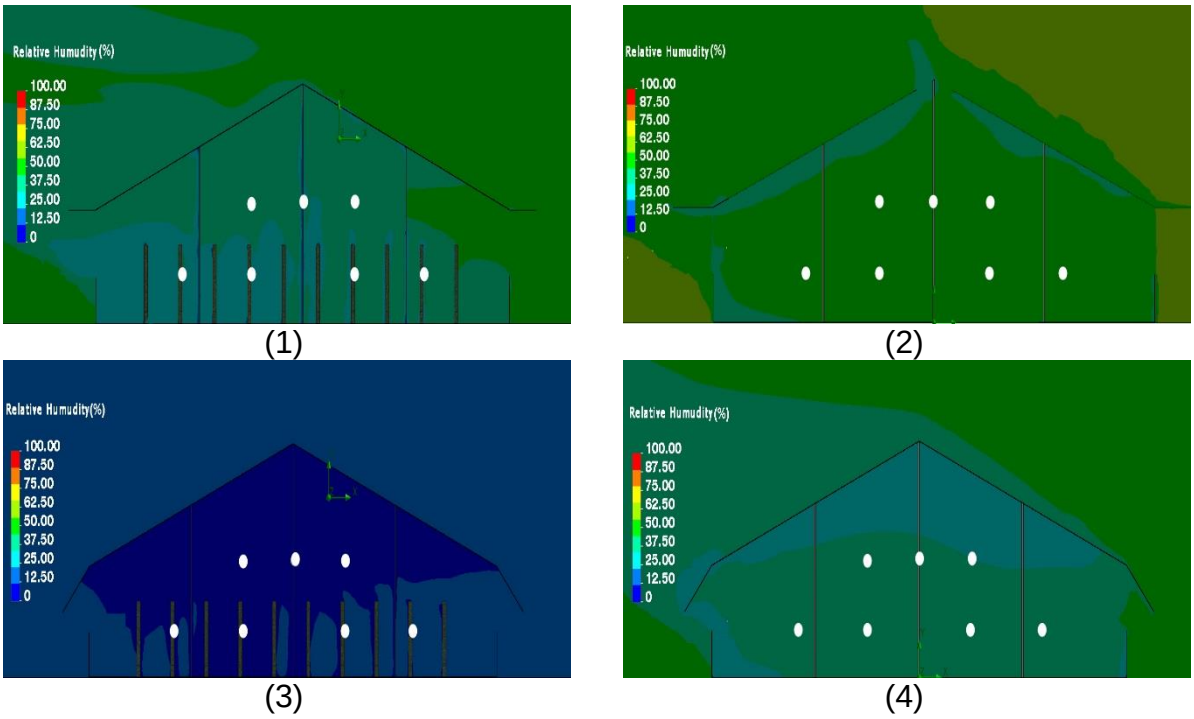

Figure 2. Simulated relative humidiy values for number 1,2,3,4 greenhouses

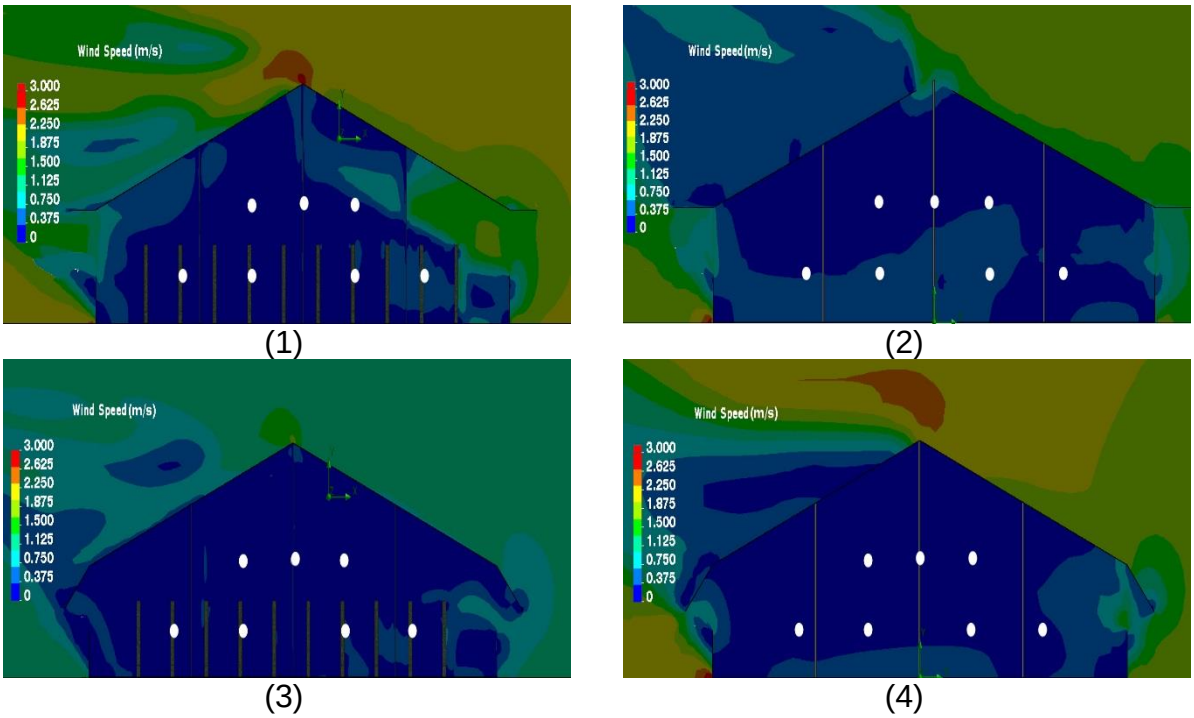

Figure 3. Simulated wind speed values for number 1,2,3,4 greenhouses

When examining the significance level belong to temperature values obtained from calculations, for number 1,2,3 and 4 greenhouses, it was found as 93.6% $\left(\frac{42.2-39.5}{42..2} * 100\right)$, 98.0%, 83.3%, 97. 6% respectively.

Similarly, when examining significance levels between measured and simulated relative humidity values, it was found as 89.2% $\left(\frac{38.3-34.1}{38.3} * 100\right)$, 94.6%, 64.5% and 96.1% for number 1,2,3 and 4 greenhouses respectively.

Finally, significance levels between measured and simulated wind speed values were determined as 100% $\left(\frac{0.3-0.3}{0.3} * 100\right)$, 92.9%, 71.5% and 80.9% for number 1,2,3 and 4 greenhouses respectively.

4. Conclusion

As a result, largely similarities were found between measured and simulated values. The most suitable combination for cultivation inside greenhouse was determined with 95.1% significance level in number 2 greenhouse (90° window openness and 0.10 plant height). So, CFD can use as a successful software to determine the most accurate combination.

5. References

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