Using Computational Fluid Dynamics to optimize the design of a commercial scale greenhouse for Western Turkey weather conditions

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Abstract

One of the most important aspects in modern greenhouse horticulture sector is to maximize the profitability by customising both the design of the construction and HVAC systems to local conditions.
Aim of the present study is to optimize the design of a 1 ha commercial scale greenhouse for Western Turkey weather conditions using Computational Fluid Dynamics. As the process of natural ventilation has a key role to greenhouse environment and is dominated by construction and wind characteristics, two designs of a typical venlo- type greenhouse with continuous roof openings and 9.6 and 8.0 m span- width respectively were simulated, focusing mainly on summer weather conditions. The ventilation rate in terms of air changes per hour for both designs was calculated by simulating the decay tracer gas method . The crop (tomato) was simulated using the equivalent porous medium approach by the addition of a momentum source term, due to the drag effect of the crop. Wind characteristics, temperature and humidity of outside air and application of insect nets on the openings , were specified to set up the 3D CFD model. The numerical analysis was based on the Reynolds- averaged Navier- Stokes equations in conjunction with the Realizable k- ε turbulence model with no- equilibrium wall functions.

The computational results show that the ventilation rate mainly is influenced by the temperature differences and less than wind speed. At high wind speeds the reduction of the air temperature due to natural ventilation by decreasing the span- width from 9.6 to 8.0 m is small. Wind direction has small influence to the ventilation rate (lower when is perpendicular to the ridge). Using insect nets has negative

effect to the ventilation rate but positive effect to the air temperature uniformity.

Further calculations were carried out for the design with span- width of 9.6 m, in order to determine the influence of different control systems to greenhouse environment.

These systems, such as energy and shading screens, cooling by fogging, CO_2 supply and recirculation fans were integrated in the initial simulation model. The results were evaluated in terms of application, operation and control, inside climatic conditions, crop production, energy consumption and cost of installation and maintenance.
The computational results show that a venlo- type greenhouse with span width of 9.6 m, equipped with continuous roof openings, insect nets, combined screen used for both energy saving and shading purposes, CO_2 supply and cooling system by applying fogging, is able to provide the optimal environmental conditions for tomato crop under Western Turkey weather conditions.

Numerical techniques are proved to be a useful tool to customize the design of commercial scale greenhouses to local conditions. In addition, useful conclusions were obtained about the limitations of computational approach showing that further research is needed in order determine in detail the boundary conditions as they strongly influence the computational results.