Energy and Buildings 87 (2015) 293–301

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

A simple model for ventilation rate determination in screenhouses

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ARTICLE INFO

Article history:
Received 16 September 2014
Received in revised form
17 November 2014
Accepted 20 November 2014
Available online 26 November 2014

Keywords:
Screen
Shading
Insect proof
Porosity
Discharge coefficient
Wind effect coefficient

ABSTRACT

The objective of this work was to study and model the ventilation rate in screenhouses. Thus, microclimate variables and crop transpiration as well as the air velocity were measured in three screenhouses covered by different screens: (i) a clear insect-proof screen, (ii) a white insect proof screen and (iii) a green shade screen, with values of shading factors to solar radiation measured in the lab of about 13%, 34% and 36%, respectively. The porosity of the screens was found 0.46 for the insect proof and 0.63 for the shading screen. The ventilation rate was estimated using the decay rate 'tracer gas' method, using the water vapour as tracer gas. The results showed that the insect proof screens reduced at the same rate the inside screenhouse air velocity, since they had the same geometrical characteristics. The internal air velocity in the insect proof and the shading screenhouses was about 20% and 44%, respectively, of that measured outside. The ventilation rate data obtained were used to calibrate a model that can be used for the prediction of ventilation rate in screenhouses, taking into account the geometrical characteristics of the screens used and of the screenhouse and the outside wind speed.

1. Introduction

Screenhouses are steadily spreading around Mediterranean regions and especially in Israel, southern regions of Spain, Italy and Greece. Those low cost structures protect covered crops from environmental (wind, hail, excessive radiative loads during hot period of the year) and biological (pests, birds, bats) pressure factors, while reduce pesticide applications (case of insect-proof screenhouses) and irrigation water needs, increasing in this way the water use efficiency [1–3]. Using screens to protect horticultural crops improves the microclimate, promoting crop productivity and fruit quality [4–6].

Screen physical and optical properties are the main factors that affect the resulting microclimate inside an enclosure i.e., screenhouse or greenhouse with screened openings. The optical properties of screens affect the construction's transmission to solar and thermal radiation and accordingly determine their heat load [7–10], while the physical properties of screens affect the natural ventilation performance of the enclosures [10–17], which is the only means of removing the excessive heat load in screenhouse structures, which negatively affects the productivity and quality of open field-grown crops [12,18]. Concerning the physical properties of screens, their geometrical characteristics strongly affect screens' permeability to air flow. The pressure drop through screens is related to screen porosity and geometry and can be determined either by Forchheimer's or by Bernouli's equation [19–21]. The porosity of a woven screen that is made of a monofilament thread and that has a simple texture was determined by 2-D or 3-D geometric analysis [22,23] or with specifically developed software [24], while, for the case of screens with complex texture, the image analysis is proposed (microscope or image processing software) [7,25]. Determination of the aerodynamic characteristics of screens can be done through wind tunnel measurements [19,26,27].

Several studies have been devoted to the relationship between inside and outside air velocity in screenhouses [1,8,11,12,28–31]. Tanny [13], in his review presented a summary of literature data on the effect of screen covers and screenhouses on air velocity. The ratio between inside to outside air velocity referred was ranging between 0.2 and 0.7. Furthermore, Tanny et al. [11,31] studied the ventilation performance of various commercial screenhouses of different size (covered ground area ≈0.66 and 8 ha; Height = 3.2 m and 6 m). The air exchange rate was found to range between 7 and 33 h^{-1} for wind speed between 1.5 and 3.5 $m\,s^{-1}$. Tanny et al. [31] who studied the volume flow rate in a banana screenhouse compared their results with those obtained by Tanny et al. [11] in a pepper screenhouse and by Demrati et al. [32] in a banana

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http://dx.doi.org/10.1016/j.enbuild.2014.11.057
0378-7788/