

## Natural ventilation by stack effect in multi-span tropical greenhouse structures

### ABSTRACT

Natural ventilation is defined as the number of volume air exchange per hour per unit floor area. It is necessary to reduce high indoor air temperature and humidity. In addition, it also maintains carbon dioxide concentration as outside of the greenhouse. Natural ventilation is preferred because ventilation opening is built in the greenhouse, cheaper construction cost, and no energy and maintenance are required as compared to the mechanical ventilation system. A mathematical model to quantify natural ventilation rates by stack effect was developed and verified under the multi-span of large-scale greenhouse structures. Four naturally ventilated tropical greenhouse structures had been designed and constructed at MARDI. The structures are single, double, triple and quadruple spans that have floor areas of 500 m<sup>2</sup>, 1,000 m<sup>2</sup>, 1,500 m<sup>2</sup> and 2,000 m<sup>2</sup> respectively. This paper presents the validation of model developed to quantify natural ventilation rates by stack effect inside the constructed structures, which is very crucial of high in-house temperature built up in the tropics. Moreover, the effects of height on ventilation rates were also discussed. The regression equations of stack effect ventilation rates against temperature differences between inside and outside structure were found to be  $s = 0.0221 \hat{T}^{0.4945}$ ,  $s = 0.0149 \hat{T}^{0.4933}$ ,  $s = 0.0117 \hat{T}^{0.4917}$  and  $s = 0.0098 \hat{T}^{0.4906}$  for single, double, triple and quadruple spans respectively. In addition, the coefficient of determinations shows strong relationship with  $R^2 = 0.9999$ ,  $R^2 = 0.9999$ ,  $R^2 = 0.9998$  and  $R^2 = 0.9998$  for single, double, triple and quadruple spans respectively. The comparison between calculated and measured in-house air temperatures has shown that they are significantly comparable to each other. The effects of three levels of height (3.4 m, 4.0 m and 5.0 m) between the top and bottom openings on ventilation rate were also studied. The results showed that the ventilation rate increased with increase in heights (distance between middle of side opening and middle of roof opening) of structures.

**Keyword:** Natural ventilation; Stack effect; Multi-span; Greenhouse structure