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Research Paper :

Thermal modeling and its experimental validation in predicting and controlling environmental parameters inside a greenhouse

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ABSTRACT

The present work was carried out to study the thermal behaviour of greenhouse by developing a suitable analytical model by which inside environmental conditions can be predicted corresponding to the outside atmospheric situation. Based on the predicted inside conditions, heating and cooling requirements for a particular crop can be decided to maintain suitable environment for the crop. The various controlling parameters *i.e.*, solar radiation, ambient air temperature, transmittance of greenhouse cover, ventilation, relative humidity etc. have been taken into consideration for studying the thermal behaviour of the naturally ventilated greenhouse. For quantitative analysis of the model developed, numerical calculations have been made to predict the effects of the above controlling parameters on the thermal behaviour of the greenhouse. The model developed has been validated for typical days in the months of September 2009 to February 2010 to know its accuracy and found to be in fair agreement between experimental and theoretical values. Various controlling parameters can accordingly be adjusted suitable for the better growth of a plant inside the greenhouse after studying the thermal bahaviour of greenhouse through the model developed.

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The control of various environmental parameters like solar radiation, air temperature, transmittance of greenhouse cover, ventilation, relative humidity inside the greenhouse, suitable for favourable growth of plant can be studied mathematically by developing a suitable thermal model, which is required to optimize those parameters involved in either heating or cooling of greenhouse. The modeling can also be used to optimize greenhouse air temperature (one of the important constituents of the environment inside the greenhouse) for higher yield of a plant inside greenhouse for a given climatic condition (Singh and Tiwari, 2000). The objective of designing a greenhouse is to maximize yield from a plant by providing suitable environmental conditions. Thermal modeling requires basic energy balance equations for different components of greenhouse system for a given climatic (solar radiation, ambient air temperature, relative humidity, wind velocity etc.) and design (volume, shape, height, orientation, latitude etc.) parameters. Basic knowledge of heat and mass transfer is also of great importance in deriving energy balance equation for heating and cooling operations of a greenhouse under given climatic conditions (Nelson, 1985). The transfer of heat energy occurs as a result of driving force called temperature difference and mass transfer takes place in the form of evaporative heat transfer.

To facilitate the modeling procedure, a greenhouse is considered to be composed of a number of separate but interactive components (Sharma, 1998). These are greenhouse cover, the floor, the growing medium, enclosed air and the plant. The crop productivity depends on the proper environment and more specifically on the thermal performance of the system. The thermal performance of a greenhouse can be studied with the help of a mathematical model with suitable assumptions. Energy balance equations are derived to formulate the model, which permits the prediction of environmental conditions in a greenhouse from outside atmospheric conditions (Das, 2010).

In this study, an attempt has been made to develop a mathematical model based on energy balance equations for each component of the greenhouse. The mathematical model so developed would be validated by the recorded experimental findings for its applicability in enhancing production and productivity of a crop in a given climatic condition with the following objectives to develop a thermal