Chapter 1

INTRODUCTION

1.1 Background

Since ancient time mankind has been aware of the fact that a wise modification of the environment could improve the productivity of crops. For instance, the fact that light transmitting shelters could create a suitable environment was certainly known to the Romans, as the Emperor Tiberius used to eat a cucumber daily (Plinius, 77 A.D.). The use of greenhouses for commercial agricultural production had to wait until the technology became advanced enough in late eighties for the products to be sold at competitive prices in the national and international markets. After the advent of plastics application in agriculture in the early nineties, greenhouse technology evolved as a breakthrough in the agricultural production technology. It has integrated market driven quality parameters with production system profits. Today, the expertise is such that, in principle, it is possible to let the climate control computer to produce the microclimate desired by the grower according to the need of a particular crop with benefit-cost ratio more than one (Bakker and Challa, 1995).

Greenhouse technology has a vital role to play in Indian horticulture by increasing the availability of fresh vegetables, fruits and flowers and thereby leading to better nutrition and improved standard of living. Greenhouse technology development in India began in the early eighties and got boosted in the nineties due to increased emphasis and financial support received in the horticultural sector (Gupta and Chandra, 2002; Tiwari, 2003). Technology advancement in greenhouse started with design and development of galvanized iron pipe framed structures of Quonset shape with inadequate ventilation suitable for winter months to the modified frames of Saw tooth greenhouse with relatively more height with top and side ventilation for summer months. Summer cooling using fan and pad system with exterior shading and different modes of evaporative cooling brought the cooling efficiency to 85% by optimizing relevant parameters. Several efforts have been made to develop location-specific greenhouse ranging from large multi-span greenhouses with ridge ventilation to Sawtooth wave designs with ridge and side ventilation (Tiwari and Gupta, 2002; Sharan *et al*., 2008; Sethi, 2009).

Although greenhouse industry in India experienced a steep growth in the early nineties, a lot of apprehensions such as the lack of appropriate designs for local agro-climatic conditions, economic evaluation of the structure with various crops and quality produce to compete in the international market made this industry sick. Studies on the failure of greenhouse ventures in India, particularly in hi-tech floriculture revealed high cost of cultivation, high energy requirements, high interest rates, over invoicing and lack of interest as major reasons. In addition to the prevailing climatic conditions, the success of greenhouse ventures also depends on the choice of crops, varieties, appropriate environmental control and market accessibility. Advocating cost-effective technology, exploring energy-efficient greenhouse designs and making them more suitable to local climatic conditions are some necessary actions to bring the greenhouse industry back to its original condition (Chandra, 2002).

A greenhouse can be defined as a "framed or an inflated structure with a transparent or translucent material in which crops could be grown under the condition of at least partially controlled environment and which is large enough to permit persons to work within it to carry out cultural operations" (Tiwari, 2003). The greenhouse is now better understood as a system of controlled environment agriculture (CEA), with a precise control of air, temperature, humidity, light, carbon dioxide, water and plant nutrition. The inside environment (microclimate) of a greenhouse is controlled by growth factors such as light, temperature, humidity and carbon dioxide concentration. They are scientifically controlled to an optimum level throughout the cultivation period, thereby increasing the productivity by several folds. Greenhouse also permits to cultivate four to five crops in a year with efficient use of various inputs like water, fertilizer and seeds and plant protection chemicals. In addition, automation of irrigation, precise application of other inputs and environmental controls by using computers and artificial intelligence is possible for the acclimatization of tissue culture plants and high-value crops in greenhouses.

Greenhouse microclimate is primarily affected by the latitude of a place, orientation, shape, size, properties of cladding material and type of ventilation system. Apart from these factors, canopy cover and bare soil surface inside the greenhouse also influence microclimate (Singh *et al.*, 2006). A well designed greenhouse can provide necessary climatic conditions to allow adequate light transmittance, low heat consumption, sufficient ventilation, high structural strength and good overall mechanical behavior at low construction and operating costs (Elsner *et al.*, 2000). The most important climatic factors influencing the structural design and the quality of indoor microclimate are temperature, global solar radiation, precipitation and wind velocity.

Predicting the microclimate inside a greenhouse can help growers to manage crop production and designers to improve ventilation and actuating systems. The internal microclimate can be investigated by field experiments and simulation. As compared to the physical modeling, simulation modeling can be performed quickly with less expense, more flexibility and repetitive ways. Some computer models for simulating the microclimate as a function of greenhouse thermal properties and outdoor climate have been developed in the past for the Indian climatic conditions (Chandra *et al.*, 1981). However, these models ignore the effects of natural ventilation and transpiration of crop as a means of cooling. Therefore, development of a reliable computer model for simulating greenhouse microclimate taking into account the effects of shape and type of ventilation is necessary.

Climatic conditions of Eastern India are adverse and capricious in nature. It requires protection not only from external climate but also from high summer temperatures to prevent scorching effect on the crop. Control of greenhouse temperature during peak summer by modifying the design and adopting suitable environment control strategies is of great significance for the year-round cultivation of crops. Earlier studies conducted at Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, West Bengal using the Quonset design of greenhouse indicated that the temperature during the peak summer rises up to 50 °C with a vertical profile gradient of 5 °C (Tiwari, 2007). Fogging with natural ventilation from the sides has been reported to be effective in reducing the temperatures during summer months for vegetable production. However, no studies have been carried out focusing on the variation of temperature in a naturally ventilated greenhouse with ridge and side ventilation for floricultural crops. Therefore, the practice of greenhouse cultivation of crops requires substantial amendments for subtropical Indian conditions to meet the local requirements right from design to environmental control. Performance evaluation of established designs to explore their suitability for raising high income generating crops and the development of naturally ventilated greenhouse with a provision to vary ventilation extent are necessary in order to find out a suitable design for year-long desired climate.

Cooling is considered as a basic necessity for greenhouse crop production in subtropical regions of India. Development of a suitable cooling system that can provide congenial microclimate for crop growth is a challenging task as the design is closely related to the local environmental conditions. Moreover, the selection of an appropriate technology for cooling depends on the type of crops to be grown, maintenance, ease of operation and economic viability (Sethi and Sharma, 2007). Hence, understanding the physical processess (geometrical and thermal) of a greenhouse and their quantification as a function of size, shape and external weather helps in the development of a suitable cooling system (Bot, 1983). There is a need to identify suitable and cost-effective cooling methods to alleviate high temperature in the greenhouse during summer months of typical subhumid subtropics of India. The evaluation of microclimate in different designs of a greenhouse and establishing physical and physiological relationships of crops is also necessary for the greenhouse designers to improve cooling system that is suitable for crop growth under varied climatic conditions.

Another passive method to reduce the intensity of transmitted radiation in greenhouse is by providing shade nets from exterior side or coating with white paint (white wash) on covering material (Bailie *et al*., 2001). The method commonly adopted by the greenhouse growers for floriculture is by placing shade net screens inside the greenhouse. This shading technique blocks part of photosynthetically active radiation (PAR) which is useful for photosynthesis. (Cerney *et al*., 1999; Zanon, 2000; Glacer *et al*., 2000). However, with the adoption of new cool plastic films having special cover properties of near-infrared reflection during the day and far-infrared reflection during night, it has become possible to reduce the thermal load of a greenhouse (Hoffman and Waaijenberg, 2002; Impron *et al*., 2007). Other cladding films such as ultraviolet blocking films can be effective for inhibiting insect activity but does not have effect in reducing thermal load inside the greenhouse (Mutwiwa *et al*., 2005; Kumar and Poehling, 2006). Diffused films are other alternatives which can promote the penetration and then the absorption of light inside the crop cover by producing less thermal radiation in the greenhouse. The information related to the design of naturally ventilated greenhouses for floricultural production is scarce for Indian conditions. Therefore, there is a need to carry out an in-depth investigation concerning design of naturally ventilated greenhouse to create favorable climatic conditions for crop growth.

Considering the above facts and research need, this study was undertaken with overall objectives to investigate the effects of greenhouse design parameters, ventilation openings (both roof and side openings) and cladding material on the internal climate as well as crop performance and to identify a cost-effective cooling method to reduce high temperature in the greenhouse during summer months for crop cultivation in the subtropical regions of India.

1.2 Objectives

The specific objectives of the study are as follows:

(i) To investigate the effects of greenhouse geometry, ventilation openings and cooling methods on greenhouse microclimate.

(ii) To evaluate the efficacy of new cladding materials of greenhouse.

(iii) To assess the suitability of gerbera cultivation under greenhouse conditions.

(iv) To develop and validate a mathematical model for simulating greenhouse microclimate in subtropics.

1.3 Hypothesis

The present study is based on three hypotheses. Firstly, as the microclimate varies in different designs and shapes of greenhouses for crop production and suitable modification in greenhouse design parameters such as size, shape, ventilation area and shading would produce desirable effects on the microclimate and crop performance under subtropical Indian conditions. Secondly, varying the extent of ventilation through rollup sides and placing shade nets of different perforations from the interior side of the greenhouse would produce the microclimate suitable for raising floricultural crops under subtropical Indian conditions. Thirdly, high summer temperatures in the greenhouse could be controlled by adopting new cladding films with different optical properties. The combined effect of ventilation and cladding material is expected to reduce high summer temperatures to a desirable extent and thereby producing favorable conditions for crop production in subtropics.