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# Optimisation of Greenhouse Climate and PAR at Maitri

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## Abstract

The optimization of greenhouse climate at Maitri station in Antarctica is described. Strategies for controlling temperature, humidity, light and CO2 concentration are described. Heating load has been estimated. July was the coldest month and required most heating. Annual heating degree days at 25° C indoor temperature were 13277.3, while those for 20° C and 15° C indoor temperatures were 11452.3 and 9627.3 respectively. Annual heating loads at 25, 20 and 15° C indoor temperatures were 77038.56, 66449.04 and 55859.28 MJ respectively. Monthly heating loads varied between 4424.88 and 8993.52 MJ at 25° C indoor temperature. Annual heating loads varied in accordance with the greenhouse temperature as

$$Hmj = 24166.57 + 2114.04 * Tg$$

Maximum PAR (Photosynthetically Active Radiation) level at the ice surface reaches upto 90000 lux. PAR levels inside the greenhouse varied between 100 and 45000 lux during polar day, while artificial illumination of 11225 lux to 20000 lux was provided during dark period through HPSV and fluorescent lamps. Temperature between 15 to 20 °C, relative humidity of 64% and CO2 level of 400 ppm was maintained. Thus optimum environment for plant growth was maintained inside the greenhouse.

## Introduction

Antarctica, the most isolated continent, has only *2%* of its area as free of ice. Apart from snow algae, lower species of plant kingdom viz. moss and lichens are found in these zones. Antarctic water and soil have a little amount of nutrients, so the growth of these species is poor. The severe Antarctic climate limits the number of land plants that are able to grow. Higher plants can not survive here because of extremely low temperatures; although two vascular plants: *Colobanthus quitensis* and *Deschampsia antarctica* have been reported to grow in Antarctic peninsula. In order to grow plants in Antarctica, protected cultivation is the only way as outlined by Joshi and Banerjee (1988) and Kononov and Kiran (1988). Intensive production of vegetables is possible in greenhouses under controlled environment. In order to study plant growth and yield of vegetable crops, a greenhouse was constructed at Maitri station during the IX Antarctic Expedition. The strategies for controlling the optimum environment for plant growth inside the greenhouse are described in this paper.

## Materials and Methods

Various parameters and their control are discussed below. Thermometers, thermohygrographs, luxmeter and gas analyzer were used for recording data.

*Temperature:* Temperature is a basic factor controlling plant growth and development. Most of warm crops require a temperature of 15 to 30 °C, while cool crops require a temperature of 1 to 15 °C. Temperatures are to be maintained in such a way that a higher day-time temperature is followed by a lower night-time temperature. This is referred as thermoperiodism. The temperature is controlled by a temperature controller. Six hot water radiators, installed inside the greenhouse provided 18000 Kcal of heat per hour. Additional electrical heaters were used at low temperatures. A day-night temperature regime of 30 °C and 15 °C was achieved. Average temperature inside greenhouse was 24 °C, while the ambient temperature was 0.4 °C.

*Humidity:* Plants require relative humidity levels of 50 to 80%. Low humidity increases transpiration losses, while high humidities increase incidence of the diseases. An intermediate level is preferred. Relative humidity was maintained at 64% level by employing humidistat/humidity controller with two humidifiers. Optimum level of humidity should be 60 to 70% (Kononkov and Kiran, 1988).

*Light:* Light, an essential requirement for photosynthesis and plant growth, is governed by three basic processes viz. photosynthesis, photomorphogenesis and photoperiodism. Photosynthesis and photomorphogenesis are responsible for plant growth, while photoperiodism helps in flowering. Plants enjoy a photoperiod of almost 24 hours during polar day and none during polar night.

*PAR:* The PAR (Photosynthetically Active Radiation) level inside greenhouse varied from 100 lux to 45000 lux. Artificial illumination was provided through HPSV lamps and fluorescent tubes/lamps upto 20000 lux. Day-length could be adjusted by setting the required time in clock/timer. A combination of HPSV and fluorescent tubes was utilised for proper morphogenesis as described by Sase *et* al.,(1988). The artificial illumination was controlled by a clock/timer, adjustable upto 5 minute interval. The luxmeter (Yorko make) were employed for collecting data. The time was measured by electronic clock in GMT.

*$CO_2$ Concentration:* Plants fix carbon during photoperiod through process of photosynthesis. It is a basic requirement for plant growth. The normal $CO_2$ level inside the greenhouse was found to be 400 ppm, while the ambient level is 350 ppm. This implies that an enriched $CO_2$ level existed inside greenhouse. Higher growth and productivity result at higher $CO_2$ levels. In order to enrich the $CO_2$ concentration during high PAR levels, $CO_2$ was forced into greenhouse through an exhaust fan that pumped exhaled air of the corridor into the greenhouse.

## Discussion

Antarctic climate poses a great challenge for engineers and plant scientists. Good controllers are required. Fig.1 shows the actual set-up at Maitri station for environment control. Because of severe Antarctic climate, greenhouse requires a great amount of heat. Heating degree days at Maitri for different values of indoor temperatures are presented in Fig.2. The greenhouse structure requires to be perfectly sealed/airtight so as to minimise the heat losses. Figs.3 & 4 show the monthly and annual heat loads. Highly significant regression equation between greenhouse temperature and heating load was found to be as under:

$$Hmj = 24166.57 + 2114.04*Tg$$

This equation predicts annual heat load in MJ at any greenhouse temperature (°C). Thermal screens help in reducing heat loss (Porcelli, 1988; Bailey, 1988;

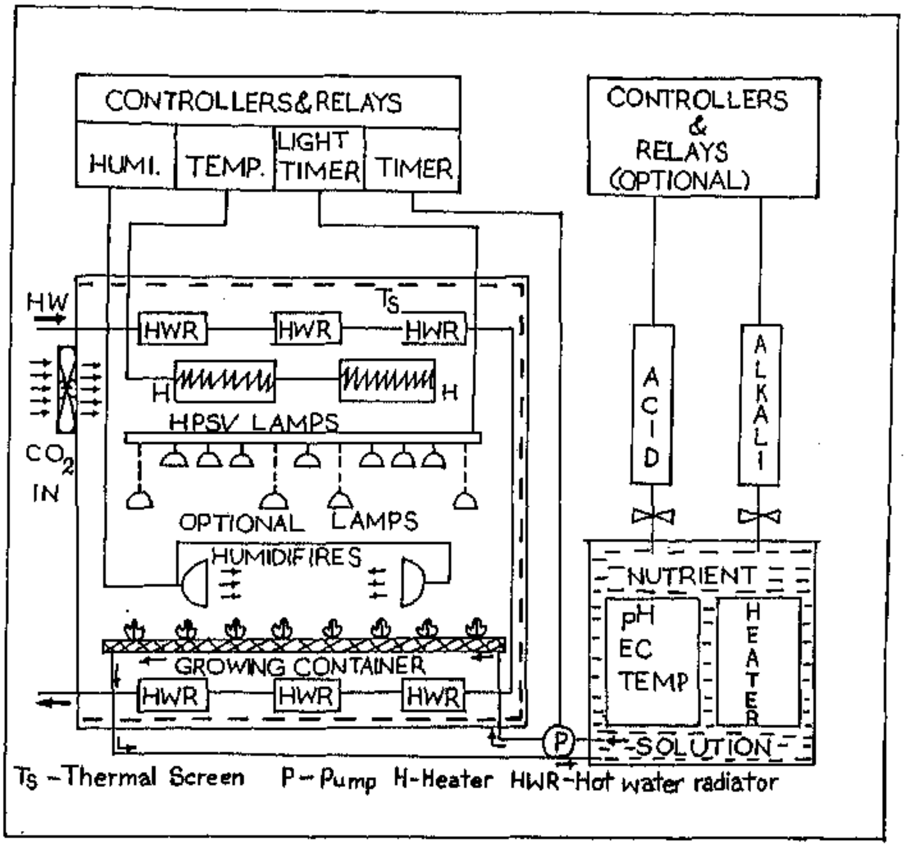


*Fig. I, Environmental control set-up for greenhouse at Maitri,*

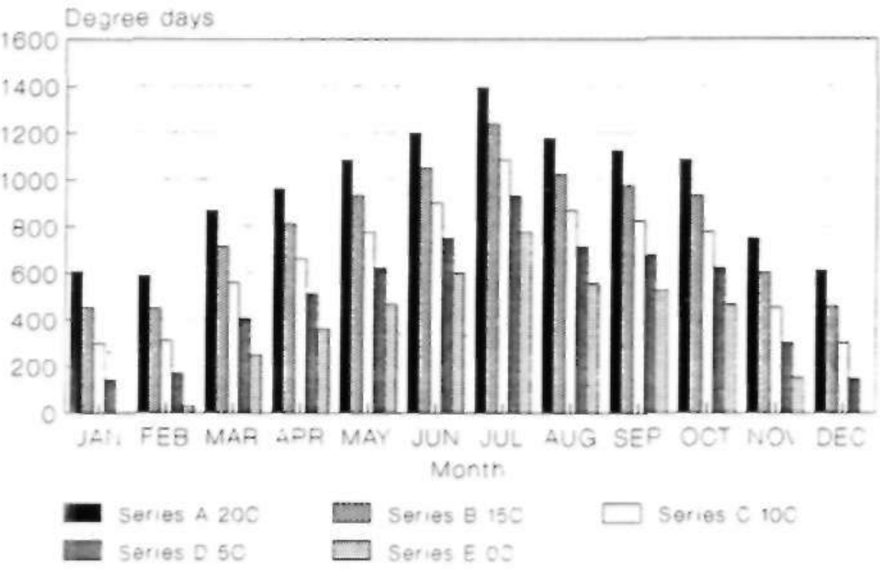


*Fig.2. Heating degree days at Maitri for different values of indoor temperatures.*

Ogura;. 1988). Latent heat storage (Nishina *et al.,* 1988) can be utilised but it is not technically feasible. Similar is the case with heat buffers (Raven, 1989).

Plants respond to environment in a number of ways. Photosynthesis and productivity are dependent on environmental factors. Photosynthesis increases at higher temprature, higher PAR level and higher $CO_2$ concentration. These factors were adjusted at appropriate levels for optimum plant growth as suggested by Lentz (1988). Egiazorove *et al.,* (1988), Anderson (1984), Nelson (1981), Berry and Downton (1984), Krug (1988) and Seemann (1979).

The PAR variations are shown in Fig.5. Outdoor PAR level of minimum 10000 lux was available for 24 hours. The peak PAR levels occurred between 0800 and 16.24 hours with average PAR levels of 40000, 39000 and 17000 lux respectively at ice surface, Maitri station area and inside greenhouse. The maximum PAR level at ice surface was 90000 lux, while the corresponding levels at Maitri station and inside the greenhouse were 80000 and 45000 lux respectively. The PAR level inside the greenhouse varied between 100 and 45000 lux. Siedentopf and Reger (1944) have measured global illumination at noon time in various northern latitudes under cloudless sky. This data shows illumination of 36000 lux for March to September and 84000 lux for June at 70 degree latitude; while in Antarctica illumination in June is zero because of polar night period. Light intensities in summer months (June

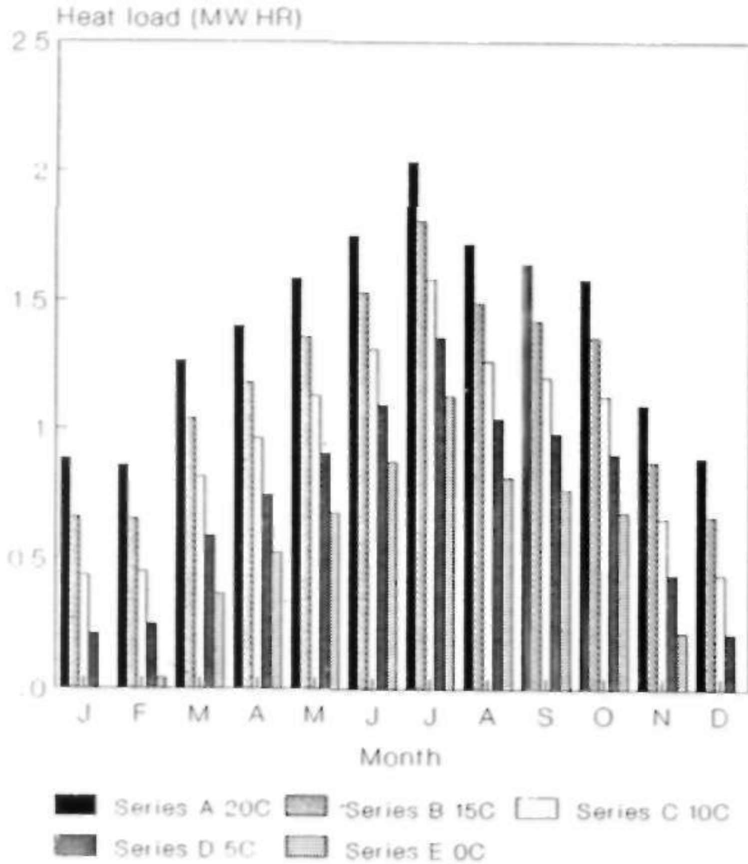


*Fig.3. Monthly heat load (MW.HR)for greenhouse for different temperatures.*

in northern hemisphere and January in southern hemisphere) show corresponding values, 84000 and 90000 lux respectively.

Clouding naturally influences both the strength of illumination as well as global radiation considerably. Under a cloud covered sky the illumination averages only 27% of that under a clear sky. However, in the presence of scattered clouds it is possible that a reflection effect may produce an increase of strength of illumination in comparison to clear day.

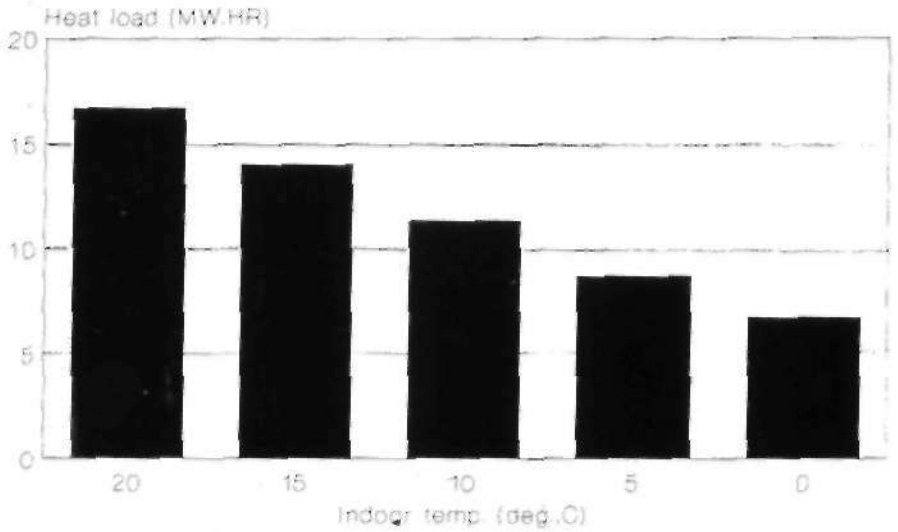


*Fig.4. Annual heat load (MW.HR)for different indoor temperatures.*

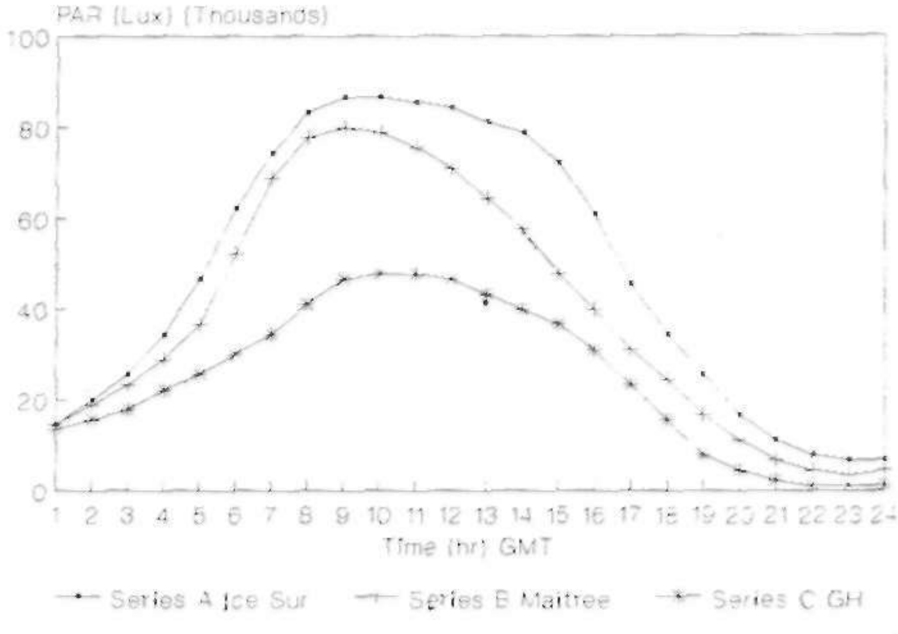


*Fig.5. PAR in Antarctica.*

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