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Phytotron- An Enclosed Research Facility for Study Interactions Between Plants and the Environment

Global climate warming can have a major impact on the functioning of crops and plants in the natural environment. A higher temperature during night time has resulted in decreased crop yields globally. It has been predicted that in the future the temperature during night time is warmer than the daytime. Due to the booming world population and increased industrial activities, it is predicted to change in the future (Smith et al., 2002). According to Meehl et al., 2007, the atmospheric CO_2 concentration is predicted to reach 730 to 1020 ppm by 2100. At the same time, it is expected to increase in global mean temperature between 1.8 and 40°C, due to the rising CO_2 concentration and other greenhouse gases. Since both CO_2 and temperature are key factors affecting the growth and developmental phenomenon of plants. Due to their crucial role and have potential influences of climate change on plant growth, global food supply, and disease risk are attracting considerable research interest in many countries (Myneni et al., 1997; Harvell et al., 2002). Nowadays various methods have been used to study the impact of climatic parameters on plant growth and development such as temperature gradient tunnel, open-top chambers, growth chambers, glasshouses, Free-Air CO_2 Enrichment (FACE), Free-Air Temperature Enrichment (FATE), and Free-Air CO_2 and Ozone Enrichment (FACO). Among all the experimental setups, phytotron is the enclosed research facility that permits the study of effects of climate variables on the plants in a precise manner.

INTRODUCTION

A phytotron is an enclosed research facility for growing plants under various combinations of strictly controlled environmental conditions, used for studying interactions between plants and the environment. The first phytotron was built under the direction of Frits Warmolt Went at the California Institute of Technology in 1949. Phytotrons spread around the world between 1945 and the present day to Australia, France, Hungary, the Soviet Union, India, England, and the United States. Moreover, they have propelled variations such as the Climatron at the Missouri Botanical Garden, the Biotron at the University of Wisconsin-Madison, the Ecotron at Imperial College London, and the Brisatron at the Savannah River Ecology Laboratory.

PHYTOTRON AND PLANT PHYSIOLOGY

Environmental stresses including drought, high temperature and salinity continue to be major factors limiting crop productivity in India and also in several developing countries. The crop productivity is low and unstable due to harsh environments and the increases in crop productivity witnessed in the recent past in large tracts of irrigated land due to high input technologies have not been experienced in these stress-prone areas. There is thus a serious concern about the impact of abiotic stresses on production systems today when we talk about food security and sustainable production in the new millennium. Therefore, national and international research programs are paying more attention to developing adaptable genotypes to various stresses. But the progress of these is not very impressive.One of the crucial requirements to define stress tolerance is also a precise characterization of the timing and degree of stress environment. Yield is the ultimate target agronomically. The adaptations and responses of plants to climate are diverse, subtle, and not fully understood. Environmental factors with a major influence on yields such as water supply, temperature, radiation, and day length often are co-vary to such an extent that it is difficult to unravel the climatic responses of plants in the field. They also interact in ways, which vary from one stage of crop development to another, and many of these aspects are crop/cultivar specific as well. Confirmation or comparisons of results under similar stress conditions often take longer periods due to seasonal variation in the weather conditions. Therefore it is necessary to complement the field studies with experiments conducted under precisely controlled environments as elegantly highlighted by Evans et al. (1985) to i) resolve which environmental factors and which physiological processes limit the response of plants to complex stress conditions, ii) to accelerate and make more reproducible many kinds of research on plants at all levels of organization from sub-cellular to the community and to enhance understanding how plants adapt and respond to their climatic environment. Even small installations with but a few controlled conditions may help significantly, but a facility on a sufficient scale, in terms of both area and variety of conditions, a valuable asset as many plants and many combinations of climatic components can be handled simultaneously and this is exactly the idea of a

PHYTOTRON MAINLY CONSISTS OF TWO PARTS

1. Complete artificial growth chambers
2. Partial control greenhouse

Growth chambers are fully controlled chambers where light, humidity, temperature, and CO_2 can be controlled with precision. The temperature in these chambers is controlled by special solenoid valves that allowed the plant to grow naturally. They have a special RAMP mode by which the temperature change is very gradual and the plant never experiences sudden spikes or dip in temperature. The temperature of plants affects many physiological processes. With several degrees of flexible settings

Figure 1.Plant Growth Chambers in Phytotron

of temperatures and programming on a ramping mode being available on most of the growth chambers, an awareness of the different consequences of temperatures on plant growth is important. It also allows the experimenter to regulate plant growth to meet his requirement along with the light and humidity controls. It is very important and critical in all biological studies to measure and control the temperature of the growing environment. Plants grown in chambers are subject to a far greater thermal load than those grown in the field. Careful orientation of plant material within the chamber area to have enough air circulation is an important factor in conditioning temperature. Wind velocities of about 0.5 to 1.0 ms^{-1} at the leaf canopy level are required to promote adequate convection heat transfer in growth chambers. The substantial dissipation of energy through evaporation largely accounts for a plant's ability to regulate its temperature within a physiologically acceptable limit. Aspirated boxes are normally used with airflow no less than $3ms^{-1}$. The influence of humidity on plant growth requires its measurement and control in growth chambers to ensure consistent plant response and subsequent interpretation of experimental results. The humidity has the most significant and direct influence on transpiration, it is the process of evaporation of water from plant surfaces into the atmosphere. The translocation of water and growth materials from roots to shoots is motivated by transpiration. Humidity also affects gas exchange through direct control of stomatal opening. The force driving transpiration is the water vapour pressure difference between the evaporating surface and the surrounding atmosphere. Usually, it is expressed in terms of Vapour Saturation Difference (VSD) or Vapour Pressure Deficit (VPD). Humidity control is also key to grow plants. In phytotron growth chambers, the increase and decrease in humidity are much more precise. Special nozzles are being used outside the chambers and these nozzles create a mist which is being mixed with air and this air is being circulated to maintain the desired level of humidity.

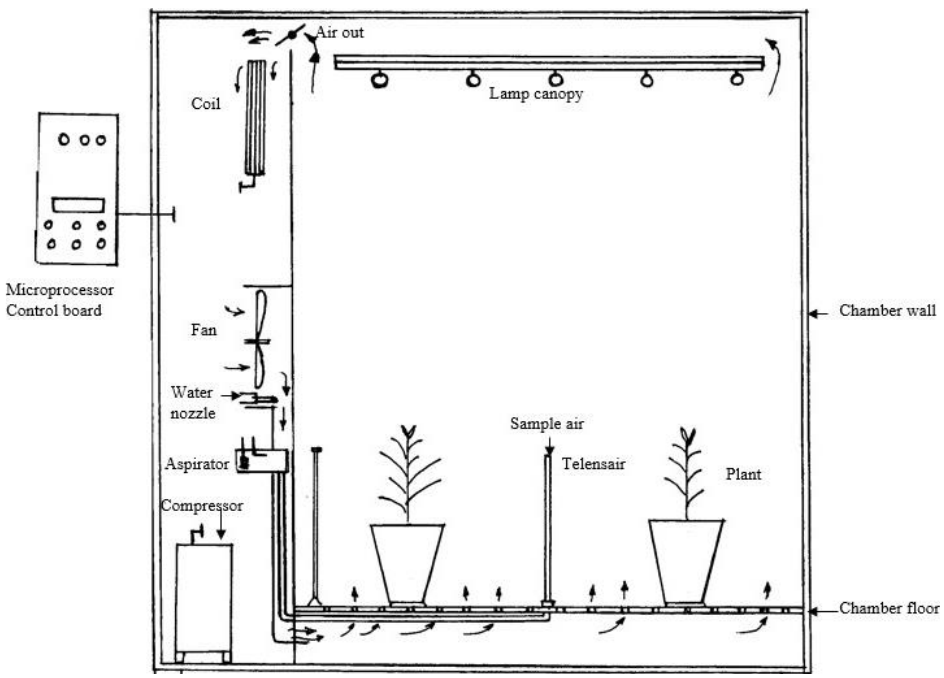

Figure 2. A diagrammatic view of plant growth chamber

Light is the most important environmental variable for plant growth and development. The quality of sunlight has become precisely mirrored in the spectral sensitivity of many plant processes. In these chambers photoperiod, *i.e.,* light duration and light quality is maintained with special fluorescent tube lights and incandescent bulbs. The mixture of both these lights sources helps in providing the correct spectrum of light. (A physiologically important measure of light is (PPF, μ mol m^{-2} s^{-1}), a combination of irradiance and spectral quality is a measure of the photosynthetic active radiation (PAR) between the wavelengths of 400 and 700 nm. Plants growing inside an enclosure would naturally involve the two key physiological processes, i.e., respiration and photosynthesis, thus dictating their growth and development phenomenon. Hence, the successful growth of plants can be control inside the chamber by monitoring and controlling the levels of carbon dioxide, as it is the common component respiration and photosynthesis process. But, CO_2 is one of the least controlled factors in plant growth chambers. Growth responses to changing CO_2 levels are hard to detect. Growth chambers generally have limited outside air exchange and the most serious problem is associated with the human presence inside and sometimes outside the chamber elevating CO_2 levels. CO_2 dependent physiological process can be affected by short term increases in CO_2 concentration. CO_2, a key component of the climatic research is well maintained with the help of the HORIBA CO_2 regulator. It has a range of 50 to 2000ppm. All plant crops can be allowed to grow under elevated carbon dioxide conditions with precision.

Greenhouses are the enclosed research facilities being used for seasonal crops. In these partial controlled experimental setups, light hours can be increased. In terms of humidity control, it can be increased only while they have more precise control for temperature as the desired level of temperature can be maintained. Besides these germinator chambers are also available which can be used to study the seed related parameters under desired climatic parameters.

- Some of the key areas of plant physiology can be worked out through phytotron.
- Analysis of crop responses against different abiotic stresses like temperature and drought
- Induction of synchronous flowering, analysis of source-sink relationships, and effect of photoperiod variation on crop growth
- Seedling based characterization for varietal identification and purity testing
- Induction of special traits like pigment expression by manipulation of light and culture conditions
- Analysis of response to herbicide levels.
- Plant nutrient interaction in hydroponics.

PRECAUTIONS IN PHYTOTRON

It should be done by all users and visitors entering the phytotron facility must change or cover their outer clothing in the changing rooms before proceeding to the sterile area.

- Phytotron laboratory coats should be worn over street clothes.
- Shoes must be as free of dirt and extraneous matter as possible.
- Safety shoes/boots should be worn if working with machinery or very heavy equipment.
- Regular users may provide their clothing for use solely in the sterile area. In that event, shoes must be cleaned and sprayed with insecticide and clothes freshly laundered.
- Name tags (available from the Manager, Biological Services) should be put on laboratory coats.
- A limited number of lockers can be provided.
- Street clothes and sterile area clothes must be kept separate at all times.
- Notebooks, cameras, and other small items should be cleaned before entry.
- Please take care not to bring pests and diseases in on fruit and vegetables.

Figure 3. Greenhouses view

CONCLUSION

Phytotrons are used mainly to investigate the role of the environment in controlling and modifying plant growth and development, hence they also play an important role in many phases of ecological research. They are an efficient method of maintaining controlled-environment facilities. They are used as plant growth chambers for biochemical studies, thus provide constant and reproducible conditions. They are also used for research like simulation modeling which requires the use of a wide range of several environmental factors at the same time. Thus, the results of the scientific studies mainly depend on the efficiency of operation, the manner in which they are used and the quality of the investigators doing the research.

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