

Proceedings of the UK Controlled Environment Users' Group

1991 SCIENTIFIC MEETING

“RECENT DEVELOPMENTS IN CONTROLLED ENVIRONMENTS”

Volume 2

Contents

1.	Solardomes: large scale closed chamber fumigation systems for controlled exposure of plants to air pollutants and elevated concentrations of carbon dioxide. T.A. Mansfield and P.W. Lucas	2 – 3
2.	Controlled environments with UV supplementation. N. Paul	3 - 4
3.	Optimal control of the greenhouse environment. Z. Chalabi	4
4.	The Ecotron - artificial climates for whole ecosystems. R. Woodfin	4 - 5
5.	Microclimate in open-top chambers. A.G. Worthington	5 - 6
6.	DoE Fumigation Laboratory at the University of Lancaster	6

CONTROLLED ENVIRONMENT USERS GROUP**1991 SCIENTIFIC MEETING****RECENT DEVELOPMENTS IN CONTROLLED ENVIRONMENTS**

The scientific part of the annual meeting consisted of five invited contributions. Summaries of these, supplied by the speakers, are attached, as are notes on the CE facilities at Lancaster visited by the Group.

SUMMARIES OF PAPERS

T.A. Mansfield and P.W. Lucas (Division of Biological Sciences, University of Lancaster)
Solardomes : large scale closed chamber fumigation systems for controlled exposure of plants to air pollutants and elevated concentrations of carbon dioxide

Large hemispherical greenhouses (Solardomes) with filtered forced-air ventilation have been in use at the Division of Biological Sciences' Field Station site, Lancaster University, since 1976. Since that time both the size and complexity of the system has increased from the original suite of 4 chambers (described by Ashenden *et al.*, 1982), to a total of 8 constructed in 1985, which incorporate double-pass (Purafil/activated carbon) filtration units and an improved ventilation system to provide approximately 2 air changes per minute (Lucas *et al.*, 1987).

The chambers were originally developed for studies with cereals and other herbaceous species, but the last 5 years has witnessed a change in emphasis to long term fumigation experiments on seedling trees. Of particular interest are experiments to investigate possible interactions between air pollutants such as O₃ and SO₂/NO₂ with other environmental stresses e.g. frost and drought.

A more recent development has been the construction of a further 4 Solardomes and the installation of a 6 tonne CO₂ storage tank specifically for studies into the effects of elevated CO₂ on plants. The physical environment within chambers is closely monitored but is not controlled. However, due to the rapid flow through of air via inlet and exit fans, temperature and humidity within each chamber remain close to the ambient (outside) values. An internal duct system made from 25 cm diameter polypropylene tubing, perforated at intervals with 2 cm diameter holes and attached to the perimeter, ensures that air distribution within chambers is very uniform and at the same time maintains a low boundary layer resistance to CO₂ and H₂O vapour transfer in the plant canopy.

Experiments on the long-term effects of elevated levels of atmospheric CO₂ on UK forestry species began in May 1991. Sitka spruce, ash and birch seedlings are being treated with either unfiltered ambient air (mean concentration 350 ppm CO₂) or enriched with an additional 250 ppm to give a mean concentration of 600 ppm. This is in the range of atmospheric CO₂ concentrations predicted for the latter half of the 21st century (Eamus, 1990). Studies are currently focused on the possible interactions between CO₂ concentration and drought stress in Sitka spruce, using both clonal and seedling material. Measurements are being made of growth, photosynthesis, frost tolerance and water relations.

In the near future 4 of the existing solardomes will be converted for experiments on the effects of elevated CO₂ on communities of herbaceous species.

References

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Eamus, D. (1990). Carbon dioxide and plant physiological processes. In: *The Greenhouse Effect and Terrestrial Ecosystems of the UK*. (Ed. by M.G.R. Cannell & M.D. Hooper), pp. 19-23. H.M.S.O.

N. Paul (Division of Biological Sciences, University of Lancaster) **Controlled environments with UV supplementation**

Research interest in the responses of plants to ultra-violet (UV) radiation has been simulated by the predicted increase in UV fluxes due to depletion of stratospheric ozone. In the UK, the Department of the Environment has funded the construction of controlled environment chambers for studying UV-B at Lancaster University.

In controlled environments wavelengths affected by ozone depletion (ie. UV-B, 280-320 nm) can be quite easily supplied by specific UV-B fluorescent tubes. However, such tubes are richer in short-wavelength UV-B than sunlight so quantification of UV-B must take into account the biological action spectrum of UV-B, i.e. biologically weighted rather than gross fluxes must be used. UV-B research also places additional demands on controlled environment lighting. High PAR fluxes (exceeding 500-600 $\mu\text{mole quanta m}^{-2} \text{s}^{-1}$) are required since plants grown at lower fluxes are predisposed to UV-B injury. Spectral quality must also be considered since UV-A (320-400 nm) and blue light are important in photorepair of UV-B damage.

Controlled environment lighting normally provides no UV-B and UV-A wavelengths below c. 360 nm are also under-represented compared with sunlight. The spectral quality within greenhouses is broadly similar to that in the growth room due to UV-absorption by glass. Current research is highlighting the diverse effects that UV-B, and by implication its absence, has on many plants. In the absence of UV-B various aspects of plant morphology, physiology and biochemistry may be modified. The broader implications of such effects for controlled environment users remain unclear but might be especially significant for those investigating the responses of plants to exogenous chemicals (since without UV-B the development of the cuticle may be inhibited and its chemistry altered) or to pests or pathogens (UV-B stimulates the production of phenolics, including those with roles in defence). Where the lack of UV-B and short UV-A is of concern supplementary UV

illumination may be a practical solution but this possibility apparently remains untested.

Z. Chalabi (Process Engineering Division, Silsoe Research Institute) **Optimal control of the greenhouse environment**

A new approach to environmental control of greenhouses is the development of dynamic optimization methods based on mathematical models describing the crop and greenhouse responses to the external environment. These methods are being used to devise environmental optimal control algorithms to meet specific objectives such as minimizing energy inputs or maximizing cost margins. Two examples are illustrated: optimal control of carbon dioxide enrichment in greenhouses and optimal control of greenhouse heating.

R. Woodfin (Department of Biology, Imperial College at Silwood Park) **The Ecotron - artificial climates for whole ecosystems**

The Ecotron is an experimental controlled-environment facility in which small communities of plants and animals (mainly insects and other invertebrates) can be assembled and grown together as model artificial ecosystems (microcosms). The facility consists of sixteen walk-in chambers in which computer-controlled systems can generate a range of climates by varying environmental conditions such as light intensity, air temperature, air humidity, rainfall and airflow.

Three features make the Ecotron unique:

- it is dedicated and designed entirely for fundamental research in population ecology
- demountable walls between chambers allow experiments to be conducted over several spatial scales
- the 16 chambers allow a degree of experimental replication not normally available in relatively low cost facilities.

Other research establishments around the world study the interaction of plants, insects and micro-organisms in controlled environment chambers. However, they usually ask specific questions related to biological or chemical control of pests and pathogens, where the physiological responses of the protagonists are of primary interest. Frequently these studies are carried out within a few very expensive chambers where the room climate is closely controlled and little experimental replication between chambers is possible. The Ecotron represents a fundamental departure from such experimental facilities, and from conventional plant growth rooms, in its purpose, design and operation.

We aim to establish in the Ecotron communities of terrestrial plants and animals capable of self-sustaining over a number of generations. This process of artificial community assembly is in itself challenging and scientifically valuable. It enables scientists to test and refine ecological theories and models that lead to an understanding of how populations interact. Once established, these microcosms will also allow research into a number of important

questions, including how food-webs are assembled, the effects of spatial scale on population dynamics and species' interactions, the effects of climate change or global warming, and pollution effects.

Specifications

Dimensions:	each chamber	2 m x 2 m x 2.2 m
	with 2 plant containers each	1.3 m x 0.85 m x 0.4 m
Water supply:	conductivity 30 μ S	
Lighting:	12 V DC 50 W quartz halogen lamps max 300 μ mol m ⁻² s ⁻¹ (1 m above floor)	
Air speed:	approx 0.06 m s ⁻¹	
Air temp:	5 - 30°C	
Dew point:	2 - 24°C	rh: 40 - 70%
Air influx:	0.25 m ³ s ⁻¹	
Air filtered and recirculated, 2% fresh/cycle		

A.G. Worthington (Department of Physiology and Environmental Science, University of Nottingham, Sutton Bonington) **Microclimate in open-top chambers**

Open-top chambers (OTCs) are pollution exposure units used internationally to examine the influence of atmospheric pollutants on the growth and development of agricultural crops. The chambers are aluminium-framed cylinders covered with transparent PVC and topped with a frustum to inhibit the ingress of ambient air. Chamber air may be charcoal filtered to remove ambient pollutants, or have pollutants injected into it.

The internal OTC microclimatic environment is significantly different from the ambient environment. This leads to differences in crop growth, development and pollutant sensitivity.

Internal radiation environment is influenced by details of the design of the chamber. A validated computer model has been developed to evaluate the spatial variation of irradiance levels of direct and diffuse solar radiation within an OTC. Model predictions suggest that under clear skies, the influence of internally reflected solar beams result in ray focusing inside the OTC. This can raise light levels in some areas of the chamber by up to 40%, while other areas experience decreased light due to attenuation by the chamber structure and specular reflection and absorption by the covers. Under overcast skies there is limited spatial variation and levels are around 90% of ambient.

Chambers substantially alter the crop thermal radiation environment. Longwave radiation is mainly from the PVC covers, which can be up to 5°C above ambient temperature. There is some thermal exchange through the open-top, as well as through the PVC, which has a transmittance of 0.14 at wavelengths above 3000 nm.

Net radiation is higher than ambient in the OTCs, and is balanced by convective and evaporative fluxes from the PVC, soil and vegetation surfaces. Ventilation influences internal temperature and evaporation and is dependent upon two mechanisms; a constant rate

artificial air input, and incursion through the open-top.

There is a marked interaction between chamber rainfall and windspeed. The chamber walls and frustum provide a sheltering effect. Total rainfall entering the chamber is on average 55% of ambient, and there is an uneven spatial distribution of rainfall.

DoE Fumigation Laboratory at the University of Lancaster

Eight 1 m³ fumigation chambers have been constructed at Lancaster University for exposing tree seedlings to reactive air pollutants and radicals at realistic ambient concentrations.

To address the problems associated with surface reaction, absorption, adsorption and desorption, the individual chambers have been designed with the maximum possible use of FEP Teflon film (0.05 mm). However, to produce a Teflon chamber of 1 m height requires a supporting framework. This framework and the inlet air supply ducting (approximately 10% of the internal surface area) is constructed from aluminium. A temperature and humidity controlled ambient air supply is purified by passage through a 50/50 charcoal/Purafil filtration system, to remove hydrocarbons, ozone and oxides of sulphur and nitrogen. This air flow is driven by an air conditioning unit (Trane BPVC 45 split system) which maintains a constant supply to each chamber of 2 m³ min⁻¹. Distribution of each chamber's inlet air, to which metered quantities of gaseous pollutants are added through a ducting system with eight adjustable vents, allows development of a turbulent mixing regime. This minimizes heating by external light sources (Philips SON-T Agro with metal halide lamps, 400 W), temperature and pollutant gradients and reduces boundary layer resistance. Measurements indicate that pollutant concentrations remain constant within the chambers and boundary layer conductance gives a minimum value of 2 cm s⁻¹.

To allow comparative analysis it is necessary to ensure that growing conditions and air quality are accurately reproduced. The suite of chambers described here have been assessed for variability in light intensity, temperature and relative humidity. Results indicate that values differ by $\pm 5 \mu\text{mol m}^{-1} \text{s}^{-1}$, $\pm 0.5^\circ\text{C}$ and $\pm 6\%$ respectively when readings are taken from similar positions in each chamber.

Initial investigation using cherry seedlings (*Prunus avium*) suggests that plants show excellent growth characteristics in these chambers.