Secretariat Phytotronique
Phytotran- C. N. R. S.
91 -GIF- sur- YVETTE
(France)

Gif-sur-Yvette, November 1971.

PHYTOTRONIC NEWSLETTER N ° 1

Some explanations.

The Phytotronic secretariat, although it has no subsidy at its disposal, thinks it is high time to start the diffusion of all news likely to be interesting or useful to Phytotronists.

We first wanted to write this Newsletter in French but, everything considered, we decided that English would be easier to read for most of the persons to whom we send it. This first Newsletter, however has been written in French as well, and those who wish to have it can ask us for it. But, for our future Newsletters, the language and the form and especially the mean of financing is not yet settled and depends on the readers' reactions and wishes.

The future depends on us all. The purpose of this Newsletter has been fully understood by the organizers of the two following meetings, who have briefly reported on their activities :

1) Controlled environments for plant growth, which took place at Label Meeting in London on March 30th 1971.

The report of this meeting is already published in Laboratory Practice, July-August. 1971.

2) Symposium ISHS - Greenhouse Climate : Evaluation of Research methods, organized by Dr, P. J. A. L. de LINT at Naaldwijk Station in the Netherlands on May 3-7, 1971.

The proceedings will be published in the next technical communication of the International Society of Horticultural Science : "Acta Horticulturae".

We heartily thank once more, these organizers for their information which would otherwise not be known by the majority of the readers.

In. order to continue our action and if possible to enlarge it, we would like everyone to send us

1) any information likely to interest those concerned by Phytotronics.

2) the addresses of persons interested in our action and wishing to receive this Newsletter.

3) ideas for the possible organization, diffusion and financial means of future issues of the Phytotronic Newsletters which can no longer be at the charge of the Gif Phytotron.

4) possibilities of contacts with reviews dealing with problems of controlled environment (particularly in Japan, Russia or USA) which could take over our action, in a not too distant future, on the international area.

We thank all the persons who have helped or will help to make our enterprise easier.

P. CHOUARD and N. de BILDERLING

A. - CONTROLLED ENVIRONMENTS FOR PLANT GROWTH.

The Institute of Biology organised a discussion meeting on this subject at the 1971 Labex exhibition in London. Introductory papers by Mr. B. CHANDLER of the Hatfield Polytechnic, Dr. G. R. SAGAR of the University College of North Wales, Bangor, and Mr. R. B. AUSTIN of the National Vegetable Research Station, Wellesbourne, were followed by a discussion opened by Professor D. H. JENNINGS of the Botany Department, University of Liverpool.
Dr. Gillian THORNE of Rotharnsted Experimental Station took the Chair.

I - Environmental requirements : Mr. B. CHANDLER, Hatfield Polytech.

This paper will attempt to relate the cost of controlled environment facilities to :

1) the required levels of environmental factors such as illumination.

2) the spacial uniformity of the environment in the controlled space.

3) the degree of precision of control required for factors such as temperature and humidity.

The following aspects of controlled environment equipment will be considered :

a - illumination : intensity - spectral quality - spacial uniformity - day/night change over.

b - temperature : variation with time - spacial uniformity.

c - humidity : need to control by some users - practical degree of accuracy of control.

d - air distribution : methods and patterns.

e - water supply : methods of applying and. controlling the application of water to the rooting medium.

f - root temperature : need by some users for separate control of temperature in this zone,

II - Uses in Teaching : G. R. SAGAR, University College of North Wales, Bangor.

Fundamental problems at all levels is that the main teaching months are the worst for plant growth (Sept. - March).

1) At primary school level very simple units based upon banks of fluorescent tubes would appear to be adequate using the temperature "control" normally operating in the classroom.

2) At secondary level with the introduction of more "Nuffield Type" studies, simple units as for (1) would also be useful, These can be placed in laboratories so that the plant material is under the eyes of the students. c. f. aquaria and vivaria.

3) At College and University level there are three requirements.

a - Preparation of material for class practicals and demonstrations.

It must be noted that class sizes are increasing particularly at elementary levels. Conventionally, material has been collected from the wild or grown in glasshouses with supplementary illumination. This makes timing difficult because of the influence of natural illumination. It is not reasonable to consider controlling the environment of these glasshouses beyond present practice. Some use is already made of controlled environments to raise algae, bryophytes and pteridophytes for class use.

b - Class practicals of the standard set-type. With small classes there are a few short periods when some control of the plants' environment seems desirable e, g. studies in water physiology.

Over-riding (a) and (b) is the knowledge that most uses are *very* short term and there do not appear to be the necessary funds available for this type of activity on any real scale.

c - Project practicals. These are of increasing importance. Students work in pairs or alone and do a simple piece of "research". Here class size is not important. Many projects demand control of the plants' environment. In the main it will be those studies that will be illustrated and discussed in the talk.

III - Uses in Research :.Mr. R. B. AUSTIN, National Vegetable Research Station, Wellesbourne,

It is a well established part of the scientific method that when studying the effects of one variable in a system, as many others as possible should be held constant. Any change in the system can then be attributed to the effects of the variable under study. For biologists this method is often difficult because of the great complexity of even the simplest organism and their manifold responses to the environment, which itself is always changing. Thus, it is impossible to carry out successive experiments in the same natural environment. This made studies of the effects of environmental factors on plant growth particularly difficult until it became technically feasible to build controlled environment chambers in which light, temperature and sometimes other factors were controlled independently of one another and of the natural environment. Much of our knowledge of light and temperature effects on plant growth has been derived from studies in such controlled environments. Newer areas of research include studies of genotype-environment interactions, of the cellular and biochemical adaptions to changes in the environment and of the role of plant hormones and the phytochrome system in producing these changes.

Existing equipment will continue to be adequate for many of these and other studies although control of atmospheric carbon dioxide concentration and improved systems for humidity control are needed. In the future, plant physiologists are likely to require higher light intensities than are at present generally used, and means of varying at will the spectral composition of the Light in the visible region. For research on the energy balance and water relations of plants chambers will be needed that have radiative cooling and lighting systems emitting visible and infra-red radiation in approximately the same proportions as in sunlight.

IV - Controlled Environments for Plant Growth. By Gillian N. THORNE, Rothamsted Experimental Station, Harpenden, Herts.
(reproduced from Laboratory Practice - July-August 1971 with permission of the Editor).

This article summarises some of the points made, not the papers as presented,

Biologists concerned with growing plants use the term Controlled Environments to mean rooms or cabinets, usually lit artificially, in which plants can be grown. An air conditioning system controls the temperature of the air, and some systems control also the humidity and the composition of the air. Growth rooms can be entered by the operator; there are few standard designs. Growth cabinets are usually smaller than rooms (up to 8 m3 volume or 5 m2 of growing area) and the operator reaches into them to handle the plants. There are various commercial designs. The rooms and cabinets discussed at this meeting were lit artificially, but transparent cabinets illuminated by sunlight are also used, for example in Australia. Environmental factors are usually, but not necessarily, controlled better in cabinets than rooms, i. e. there is less variation in time and in space within the growing area. The term phytotron is used for a collection of controlled environment facilities, frequently including air-conditioned glasshouses. as well as artificially lit space.

Environmental factors to be controlled.

Illumination is usually provided by low pressure, fluorescent tubes that can give intensities up to'a maximum of 40.000 lux or about 175 Wm-2 of visible radiation, Most plants will grow satisfactorily in half this intensity. The vertical gradient of light intensity is inevitably greater than outdoors but may be less than 30 % m - when the walls of the cabinet are lined with reflecting material. Intensities equivalent to summer daylight, of about 100. 000 lux, can be provided with high pressure mercury vapour or Xenon arc lamps. but there are considerable difficulties in removing the heat, Such intensities require a great deal of electricity : approximately 4 kW m-2 of growing area, in addition to that required for cooling. The spectral quality of light provided by existing fluorescent lamps differs considerably from sunlight..lt is satisfactory for photosynthesis but has adverse effects on some species : their floral development and morphology are different from plants grown in daylight. This probably occurs because the ratio of near infra-red (...,730 nm) to red (,v660 nrn) light is much less in the artificial sources than in daylight, even when incandescent lamps are added to the fluorescent. It is usual to switch the light on and off in a single step without attempting to simulate dawn and dusk. This seems to be satisfactory for most purposes. Lamps may be separated from the growing space by a transparent ceiling, when they require their own cooling system, or be suspended in the growing space, an arrangement easier to design and construct but that increases both the heat load on the air-conditioning system of the growing space and the infra-red radiation reaching the plants,

Temperature control of the space in which the plants grow is necessary to remove the heat from the lamps, and to provide the required air temperature. Temperatures between 5 and 40°C only are required in most studies of growth. Cooler temperatures needed for specialised studies of, for example, frost damage, are not easily obtained in most growth rooms and cabinets because the cooling coils become frosted. Two different temperatures can usually be obtained in a 24-hour period with a sudden change between day and night conditions giving a "square climate". The accuracy of control ranges from ± 1/2° C in space and time in the best cabinets to ± 1, 5°C in time and -3° C in space in the cheapest rooms. The sensors of the control system should be placed so that they sense a temperature similar to that of the air surrounding the plants. In most growth cabinets and rooms there are only small differences in temperature between parts of the plant in contrast to outdoors, Equipment for controlling temperature of the roots separately from that of the tops can be put into rooms or cabinets but may interfere with movement of the air (see below).

Complete control of the humidity of the air, including addition of moisture, as opposed to the control of dew point temperature and hence of the maximum humidity allowable, is not often provided and when it is the precision may be poor. Most biologists studying plant growth do not mind this, though variation in transpiration, which depends on the vapour pressure deficit of the air, may he more important than now realised. Control of humidity is expensive because large coolers are required to remove water and large heaters to warm the over-cooled air, as well as equipment to inject water or steam and to deionise the water should it contain many salts. Humidity control may also cause difficulties in the control of dry bulb temperature, e. g. excessive cycling.

Circulation of air through the growing space is required primarily so that the air conditioning equipment can operate. The speed and uniformity of air movement affects the spacial uniformity of temperature. If the circulating air is well mixed and moves quickly past the heat exchange equipment, a simple on-off control system can give temperatures in the growing space that are very uniform in time. The speed of air movement round the plants is frequently less than 0. 2 m sec^{-1} compared with speeds of around I m sec^{-I} over crops in the field. The direction of air movement may be or upwards or downwards or horizontal and all have advantages. The direction will be determined by the position of entry and exit points for the air and the shape and size of objects to be put in the air stream.

Fresh air needs to be added to the circulating air to replace the carbon dioxide used in photosynthesis by the plants growing in the room or cabinet. Up to 600 1 per m^2 of growing area is necessary to prevent actively growing plants decreasing the CO_2 concentration by more than 20 ppm. Alternatively, the concentration of CO_2 and other gases can be controlled in a closed air circulation system, but this is difficult in rooms or cabinets that are not airtight.

Space for growing plants in rooms or cabinets requires services such as water, and drainage and electricity for operating ancilliary equipment, In an installation operated by a secondary coolant, such as glycol, coolant outlets near the growing space may be very useful for operating ancillary equipment, e. g. for controlling root temperature.

Uses.

One of the main uses of controlled environments in agricultural and horticultural research is to study the effects of individual climatic factors. This is very difficult outdoors because the seasonal trends of daylength, daily amount and intensity of radiation, and temperature are closely correlated, as are also short term changes in temperature and radiation that constitute weather. Even when a climatic factor is altered experimentally outdoors, for exemple when light intensity is decreased by shading or the day shortened by darkening, the effects may depend on other factors, such as temperature, which are correlated or interact with the experimental ones. Studies in controlled environments have provided much of our present knowledge of the effects of illumination, temperature and humidity on growth, morphology and development of plants, even though plants grown in artificial conditions often differ from those outdoors. Such studies have also solved some practical problems. For example, work at the former A. R. C. Unit of Flower Crop Physiology at Reading University showed that the irregular flowering of All-Year-Round pot chrysanthemums was caused by lack of light during the first two weeks of the short-day treatment used to induce flowering, but that later the lack was less serious. Glasshouse trials confirmed the practical application of these experimental results.

Controlled environments will continue to be required if we are to understand the mechanisms that control the response of plants to the environment, for example, those involving endogenous growth substances and metabolic processes. Such studies are also needed to provide the basic information to formulate mathematical models of plant growth and development.

Another use of controlled environments in research is to provide reproducible conditions so that the responses of standard plants to disease organisms, pesticides, growth substances etc. can be studied. By providing growing conditions throughout the year equivalent to those obtainable in a glasshouse only in the summer, controlled environments also enable more generations to be grown than is possible in glasshouses.

Commercial users are now becoming interested in controlled environments for such uses as screening of pesticides and weed killers. Commercial horticulturists also use simple growth rooms for raising seedlings in the winter for short-team treatment of larger plants, for example, a light treatment to promote flowering in chrysanthemums, or for the tissue culture technique now being used for plant propagation.

Teachers, whether at school or university, are interested in controlled environments because the main part of the academic year is so unsuitable for growing plants in natural conditions, The variability of natural daylight makes it difficult to ensure regular supplies of material for demonstrations using glasshouses, even when these have heating and supplementary illumination. Modern teaching methods, including the "Nuffield" study programmes, endeavour to maintain the enthusiasm of students for the subject by giving them projects and presenting them with problems. For such investigations some kind of environmental control is invaluable, though it may be only a panel of lamps over a bench, making use of the crude temperature control operating in the laboratory or classroom. The spatial uniformity required by many research projects is not essential as students can be taught to recognise and compensate for spatial gradients by re-randomising the plants or using suitable statistical designs.

Cost.

The cost per m2 of growing area can range from as little as £40 for the materials required to construct a simple growth room up to £ 2,000 for a commercial growth cabinet, Most of the equipment obtainable commercially at present is too expensive to be bought for teaching under-graduates or school children, It was suggested that manufacturers should use modular construction to provide expensive versions of equipment or cheap, simpler ones that could be added to later. Controlled environment facilities for universities might be provided at a few places, each available to several universities, rather than scattered in small poorly maintained units. It full benefit is to be obtained from growth rooms and cabinets in research and education additional equipment such as that for measuring stomatal aperture, water content and metabolic processes is required to study the responses of the plant to the environment.

Problems and inadequacies.

Although the present equipment is adequate, it is unnecessarily complicated and hence unnecessarily expensive for some investigations. Further improvements are still needed. Lighting regimes in which spectral quality, maximum intensity and diurnal change in intensity more resemble sunlight will be wanted and also a microclimate and diurnal changes in temperature that reproduce average conditions outdoors. Controlled and high relative humidities are required for some studies with herbicides and plant pathogens. Humidities exceeding 95 % R. H. needed for some infections require radiation cooling systems.

People intending to set up controlled-environment facilities were warned to appoint an engineer to look after the equipment, problems with equipment that included control of humidity, and to ensure that supplies of electricity were adequate. The method of operating the equipment could affect seriously the charge for the electricity consumed with some "maximum load" tariffs. Traces of noxious substances in the air can be far more serious in growth rooms and cabinets than in conventional glasshouses because of the small exchange with fresh air. Many plastics, particularly flexible F. V. C. , are toxic to plants and have given trouble in cabinets. Industrial pollution of the air can also be troublesome and necessitate filtering the fresh air through charcoal.

Conclusions.

Growth rooms and cabinets are now generally accepted tools for biological research, and, as other sophisticated equipment, will in due course become familiar to students at university and secondary school. At present in this country there is a shortage both of standardised commercial equipment and of good standard designs for home-made equipment.

B. - LNTERNATIONAL SOCIETY FOR HORTICULTURAL SCIENCE (ISHS)

SYMPOSIUM : "Greenhouse climate evaluation of research methods".

This symposium was held at the Glasshouse Vegetable Crops Station at Naaldwijk, the Netherlands, the 3-7 May 1971 and was attended by some 80 participants from 17 countries.

The programme was as follows :

Tuesday, 4 May — Chairman : Prof. J. F. BIERHUIZEN (Netherlands)

- Welcome address by E. KOOISTRA, Director of Research Station, Naaldwi jk.
- P. GAASTRA (Netherlands) - Ranges of primary environmental effects on plants .

- J.DAMAGNEZ (France) - Analyse du bilan d'energie sous serre dispositif exp¢rimental.
- H.H, KLUETER (USA) - The phyto- engineering laboratory,
- R. BROUWER (Netherlands) - 'Dynamics of plant performance:
- D. M. PEGTEL (Netherlands) - Aspects of ecotypic differentiation in the perennial sow thisth,
- F. W. T. PENNING de VRIES (Netherlands) - A quantitative approach to respiration and production,

Wednesday, 5 May Chairman : Ir. N, de BILDERLING (France)

L. G. MORRIS (Israel) - The value of various controlled environment enclosures with respect to protected cultivation.
P. NEWTON (United Kingdom) – Growing rooms.
H. ENOCH (Israel) - C02-nutrition research.
J. F. BIERHUIZEN (Netherlands) - COZ and photosynthesis.

Thursday, 6 May Chairman : Dr. L. G. MORRIS (Israel)

- J. WARREN WILSON (United Kingdom) - Plant and climate : measuring procedures and instruments.
- D.W.HAND (United Kingdom) - CO-assimilation measurement.

Friday, 7 May Chairman : Dr. A. KLOUGART (Denmark)

- E. W. M. VERHEY (Netherlands) - Light interception and yield of peppers (Capsicum frutescens) grown under glass, in relation to plant spacing.

P. J. A. L. de LINT (Netherlands) - Life plants, a selection problem.

At the end of the symposium, the papers presented and the discussions were intriguingly summarized and evaluated by Mr. G, F. SI-EARD, Littlehampton England. After having grouped the various papers along two lines into papers dealing with :

a - Plant production : growth rooms (Newton and Klueter),
- crop physiology : C02 (Enoch) ; fruit maturation and plant uniformity (de Lint) ; mutual shading (Verhey).
- plant physiology : primary environmental effects (Gaastra) ; respiration (Penning de Vries) ; ecovariation (Pegtel) ; CO2 (Bierhuizen) ; plant performance (Brouwer),

b - Facilities and equipment : energy balance facility (Damagnez) controlled environment enclosures (Morris).
- Instrumentation and measurement : measurement of plant and climate (Warren Wilson) ; measurement CO2 (Hand) ; interception of light (Verhey).

Mr. SHEARD ended his speech with the following remarks :

When more production is needed to provide it, where quality is needed to provide that, whatever the demand should be, whether it is quantity or quality, the final objective of our research is to benefit the commercial producer and in the end the world population.

If we review horticultural research, we have, in the last 20 years, made very rapid progress. One only has. got to think back to 1950 and from that point onwards, look at the development of horticultural research and horticultural research facilities in the different countries we represent, to realize what large amount of capital has been invested in this field, and indeed what results have been attained. But when one reviews the present situation, I feel that we have reached a plateau and that the large improvements we were able to make ten years ago, are now no longer possible. Whereas in those days 10-15 % improvements were not unknown and relatively easy to obtain, for the present time we find it difficult to get 1-2 % and indeed we do struggle to do this. We must review this situation and I think, one of the most important features of this symposium is that it may have shown the way we could go on from this point to make further progress.

The thought I would like to leave with you in trying to bring together the thoughts and the discussions of these three days is that, grouped together in this room, we have a very wide range of people. I don't think we have a commercial grower in his own right, but we certainly do have the extension service, we do have representatives of experimental stations and of research stations, and indeed of universities dealing with more fundamental aspects of crop production.

I think that, if we in commercial crop growing are going to make progress in the future, we have got to go back now to look more closely at the fundamental processes within the plant. When you consider particularly the contributions in this field from Dr. GAASTRA, Dr. PENNING de VRIES, Prof. BIERHUIZEN and Dr. BROUWER and consider again the information they have put before us, and the discussions to which this gave rise, I think, one can not ignore the conclusion that, if we are going to make progress, that we have got to go back into this more detailed subject,

In fact, we have done all the easy things, we have made all the big easy developments and, as far as I can see, we are not going to make major steps forward until we have a better understanding of these more fundamental processes.

The papers have implicated the difficulties of working in this field and the amount of effort we shall have to put into these problems to make progress, yet I feel convinced that this is the area which will produce the next major steps forward,

Could I just conclude by saying how much I appreciated this symposium and particularly the range of papers we have had presented, from the practical application at one end to the fundamental research on the other, and to bring together these proceedings with the thought that we should from a symposium of this kind, look to the future and determine that we each shall look forward and each play our part to the benefit of the commercial crop producer.

The above symposium is logically continued in 1972 by two other I. S. H. S. symposia.

The first symposium is : "Basic Problems of protected vegetable cultivation" - 12-16 September 1972 in Hannover.

Convenor Chairman : Prof, Dr. H. KRUG (Institute for Vegetable
Production - Technische Universitat Hannover -
3 HANNOVER - Herrenhluser Str. 2 - West Germany)

Five topics will be discussed

1. Growth chambers, means for analysing plant growth and development (function and environment, experimental methods, special problems).
2. Transferability of results in growth chambers to greenhouse and field conditions.
3. Control of plant growth and development by the root environment (excluding nutrition factors).
4. Control of plant growth and development by climatic growth factors (temperature, light, humidity, C02).
5. Growth simulating models as a tool for plant growth analyses and control.

The second symposium is : "Water supply under glass and plastic" 18-19 Septembre 1972 in Geisenheim (Rhein).

Convenors Chairmen ; Prof. Dr. H. D. HARTMANN (Institut f. Gernttsebau)
Prof. Dr. W. U. v. HENTIG (Institut f. Zie rpflanz enbau
Hess. Forschungsanstalt €iir Wein, Obst- u.
Gartenbau - D6222 Geisenheim (Rhein) - West Germ.:

Seven topics will be discussed :

1 Basic problems of water relationship.
2. Sources and quality of the irrigation water.
3. The quantities of irrigation water used in relation to season.
4. Water and nutrient supply in relation to plant development (air humidity inclusiv).
5. The use of water for leaching purposes.
6. Water application systems with respect to plant response.
7. Water control and measurement.

Proceedings for both symposia will be published in Acta Horticulturae I. S. H. S.

"PHYTOTRONICS AND HORTICULTURAL PROSPECTS" - Tel-Aviv, March 197C

The proceedings of this symposium will be published in Paris. All inquiries should be addressed to :

Secretariat Phytotronique
Phytotron - C. N, R. S.
91 - GIF-sur-YVETTE (France)