Secretariat Phytotronieue
P.ytotron-C.N.R.S.
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Contents

I - EDITORIAL

It appears that the first two numbers of the "Phytotronic Newsletter" have had a certain success considering the letters and encouragements which we have received. Moreover, to continue our task of information we are consacriting this number, as shown in the table of contents, to the report of the "UNESCO-NSF.--SEPEL" conference on the use of Phytotrons and controlled environments for scientific research which was held at Duke University (Durham N.C.) and in North Carolina State University (Raleigh N.C.) in the USA May 22 to 27, 1972. There were discussed many problems brought up by the use of Phytotrons and controlled environments for research in plant physiology and in application in the fields of agronomy horticulture and forestry.

To write this report we used the summarized texts distributed to the participants of the conference, the notes sent to us by Professor P.J. Kramer and Dr. K.J. Mitchell to whom we are very grateful, and, of course, our personal notes.

In the end of this number, you will find some information

II - BRIEF ANALYSIS OF THE PROCEEDINGS OF THE SI1iPOSIUM

USE OF PHYTOTRONS AND CONTROLLED ENVIRONMENTS FOR RESEARCH PURPOSES.

Durham-Raleigh (U.S.A.) 22-27 May 1572

by P. CHOUARD and N. de BILDERLING

This symposium was organized by Professor Y.J. Kramer with the assistence of the "Phytotron Board" of SEPEL (Southeastern Plant Environment Laboratories). It was initially planned for the year 1966, but was delayed for technical reasons and especially because of the starting of Phytotrons in Raleigh and Durham. This symposium had obtained the accord and support of UNESCO, the NSF (National. Science Foundation) and also of Duke and North Carolina State Universities.

The choice of Raleigh-Durham with the "North Carolina Triangle Research Centre" (group of the State Laboratories and industrial laboratories inside the triangle formed by the three Universities of North Carolina) permitted the participants of the conference to visit SEPEL complex which group : 1) The Phytotron of Duke University at Durham., with its Calculation Centre and all equipment for collecting stocking, memorizing and analysis of results. 2) The Phytotron of North Carolina State University at Raleigh which has the use of a terminal of Calculation. Centre and the equipment reserved for entomological and phytopathological research. The first of these phytotrons is devoted to fundamental problems and the second one mostly to applied problems. They exchange information and work in cooperation together.

For the second time UNESCO financed a conference on phytotronics (the first was at London the 30 and 31 July 1964 (Phytotronique -Edition CNRS- Paris 1969 - 111 pp)). At the opening of the session the organizing committee honoured the memory of phytotronists who died recently : Professors R. BOUILLENNE (Liege), J.P. NITSCH (Gif) and WATSON (Cornell).

This international symposium assembled 125 participants from the following countries : Australia, Brazil, Canada, Colombia, Denmark, France, Germany, Great Britain, Hungary, India, Israel, Japan, Mexico, Netherlands, New Zealand, Peru, the Philippines, Sweden and of course the U.S.A. The USSR was the only country which has Phytotrons and was not represented, which was unanimously regretted. In spite of this lack the assembly of participants represented most of the different disciplines and trends of utilizers of controlled environments never assembled before and among them, there was a great number of persons searching for phytotronic means.

One of the essential objectives of this symposium was to explore the ways in which research accomplished in the PhyLotrons or by phytotronic means can contribute to the progress of fundamental and applied sciences. We wanted to examine particularly the most effective ways to use a Phytotron in comparison with experimentation in the fields and in controlled environments and also to have examples showed to that degree the research accomplished in controlled environments can help and solve important cultural problems. This objective was fully achieved because the time of this symposium correspond to the use of more and more equipments of environmental control and permitted to gather a great number of examples of research in this area, which it was impossible to realize by other means. The experience acquired permits to ascertain the need of "controlled environments" and "Phytotrons" as well as their improvements. Briefly, we can realize that in spite of the high costs of equipment, which ought to be decreased, the nature of the new results which we can obtain merits the allowed expenses.

The following is some brief information on the conference classified chronologically. A report will be published in the periodical "Nature and Resources" by UNESCO. Those who are interested can request more information from Professor P.J. Kramer.

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1st Part. A - The strategy of Phytotron Research (k lectures).

Chairman : F.W. WENT (USA-Reno) - In a few words the chairman introduced the problem of the evolution of science and techniques where the Phytotrons providing a new tool of research, have a great future, because they can bring together under a common denominator (the environment) a great number of different disciplines and trends,

1) P. CHOUARD (France) - The impact of Phytotrons and phytotronics on plant physiology.

The Phytotrons and phytotronics have led to a new method of thinking in modern plant physiology. In defining phytotronics, it is the meaning not the volume or the dimensions of the Phytotron which is essential because it is the extention and the application of Claude Bernard's conception of physiology : analyzing separately, at the beginning, the effects of different values of one parameter, then another etc, and afterwards the correlation between several parameters varying simultaneously.

The Phytotron, which is a means of choice for sampling the rule of Claude Bernard to plants, permits a good use of comparative physiology with finer and finer analyses : behaviour of plants, organs, tissus, cells, etc...

In this way all research has a physiological signification.

Ecology (of natural areas or cultural complexes) seeks laws and concepts by statistical analysis but this is limited, In. the same way the mathematical models of ecosystems come up on the difficulty of our ignorance of a great number of physiological factors and the values of the parameters of these factors. The role of the Phytotron is to analyze experimentally the given data to be interpreted. Also the phytotronic method makes the problems of ecology more physiological, more experimental, more functional and explanatory even those of field ecophysiology which also have their limits. Equally, the phytotronic method Makes the findings in biochemical and biophysical research also physiological by situating them in crucial moments of determined physiological sequences using the Phytotron.

As an example, the strategy of research in the Gif Phytotron was described and discussed.

2) K.J. MITCHELL (New Zealand) - Correlation of controlled environment research with field research.

There are no general universal principles to follow in establishing a correlation between controlled environment and field research. This must be done in successive steps. The conditions change depending on the country and the determined environments. For New Zealand, the control of climatic conditions helps agriculture to obtain a better production by improvement of techniques, research and productivity. The aim is to establish valuable tests rather than to make fundamental basic research. Thus we must be able to reproduce the most of the combinations of climatic conditions necessary for plant growth, each factor changing independantly. Variable natural light is replaced by artificial light, using combinations of lamps, to provide a total spectrum permitting to give the same growth results as in open fields. Electronics gives the maximum of flexibility to the available installations for research workers. The quantitative measurements obtained by the ecologists in open fields are compared with the quantitative values of rate of evolution of plant functions established in controlled conditions. They will help as a basis for the modelization and prediction of the yield in relation to the circumstances. It is, however, the physiology which must serve as a guide for it is the only one which can say what principal process in the plant is in question. The research projects are examined according to the needs to answer the maximum number of demands. All research was carried out with the help of calculators and with. cooperation between technicians and research workers. The Phytotron then serves much more as a analyzing tool and permits best understanding and interpretation of results obtained in the field.

3) C.D. RAPER (USA-Raleigh) - Cost to benefit evaluation of Phytotron research versus field research,

The following table (next page) is a comparative analysis of research costs on tobacco in Phytotron and in the field experiments.

Although the total costs in Phytotron are less than those in field experiments, the research to be undertaken in Phytotron must be carefully chosen to complete and deepen those which can be and ought to be continued in the fields, Low cost analyses and determination should be carried out in the field and the Phytotron should be reserved for high cost experiments and particularly those which depends on environment.

	Field	Phytotron
Basic cost	720 $ US	4110 $ US
Variable cost		
Nutrient accumulation	2160	720
Nutrient distribution	2160	720
Organic distribution	1400	470
Total variable cost	5720 $	1910 $
Data collection		
Labor	1400	4110
Travel : transportation 220) labor 760)	980	0
Total data collection.	2380 $	440
Total variable cost	8100 $	2350
Total costs	8820 $	6460 $

4) R. J, BULA (USA-Purdue) -- Complementary aspects of Phytotron and Field Research.

A plant growing in the field is exposed to dynamic environmental conditions. Phytotrons provide an opportunity to compartmentalize and to study each sequence of dynamic environment to determine and interpret its reaction. although without reproducing the dynamics of a natural environment. The use of Phytotron facilities in agricultural research can be summarized into three major areas : 1) provision of reproducible plant material for comparative experiments, 2) study of specific plant responses to environmental regimes and 3) study of the relationships between. various plant processes and their effects on solar energy conversion. The Phytotron can also provide foresight in predicting plant variations in response to various environmental factors and on this basis it can examine and control the value of action of each environmental sequence.

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In conclusion to this first part F.W. Went emphasized that Phytotron and field research cannot be opposed but that it is necessary to find for each the type of research which will give the maximal results. Modelization, and use of computers help to choose the best place for each research. If the physiologist works something on atypical plants he may, with the help of' the Phytotron have a better understanding of environmental action and also, of climate.

B - The degree of control provided and needed in controlled environment facilities lectures)

Chairman : H.A. SENN (USA-Madison)

1) C.H.M. van BAVEL and K.J. Mc CREE (USA-Texas) - Design and use of Phytotrons in crop productivity research.

The usefulness of Phytotrons resides in the measurement and of study such plant response functions as are virtually impossible to obtain under field conditions. However the Phytotron plants mist be grown and tested under conditions which to resemble outside conditions so that they resemble field plants with respect to the rates of carbon assimilation, transpiration rate stomatal movements and other physiological processes. These functions must be strictly controlled by computers in order to establish productivity models throughout the life of the plant.

2) P. GAASTRA (Netherlands) - Physiological aspects of environmental control in climate rooms.

The value and accuracy required should ideally be based on values and accuracies to be obtained for the primary plant reactions to environmental factors. There is no general rule but all depends on the research goal.

3) G.J. HOFFMAN (USA-Riverside) - Humidity effects on yield and water relations of nine crop.

The influence of atmospheric relative humidity on plant growth is neglected in previous research especially in greenhouses. An increase in humidity from 40 to 85 % gives an increased yield of beet, corn, cotton and pepper of over 50 %. Bean, radish and wheat yields were increased 10 to 30 %. Barley and onion yields were not benefited by high humidity. In general, plants grown at low humidity has lower leaf water, osmotic and turger potentials than plants grown at high humidity.

4) Y.B. SAMISH (USA-Georgia) --Measurerrent and control in growth chambers. The need and technique.

The effects of CO_2 concentration on photosynthesis, photorespiration and transpiration are necessarily reflected in the growth of plants. Consequently, the regulation of C02 concentration in growth chambers is not only desirable but necessary. CO_2 enrichment of the atmosphere studies have been carried out with cucumbers, sweet peppers, lettuce, roses and grasses. When the CO_2 concentration was approximately 0,1 % there was an increase in vegetative growth, rate of fruit set and resistance to disease. A "lull Point Compensating System" have been developped which control CO_2 content and quantity of removed and resupplied air. This system provides a method for measuring gas exchange accurately and economically.

5) K.J. Mc CREE (USA-Texas) - A rational definition of Photosythetic active radiation.

The most important single light measurement that can be made in Phytotrons is the flux of "Photosynthetically active radiation" (PAR). The spectral response of an "average" leaf to equal absorbed fluxes of quanta was approximately constant throughout the visible part of the spectrum. An instrument with a constant response to equal incident quantum fluxes, within the range 400-700 nm measures the actual flux of PAR with a systematic error of less than ± 10 % for any of the natural or artificial light sources likely to be encountered.

6) R.L. SCHAFER (USA-Alabama) Computer based data acquisition and process control.

Using an analogical computer, it is possible to regulate and record all factors very easy and with great flexibility. A small digital computer with 16 bits of information would make an attractive tool in phytotronic research

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Visits to Southeastern Plant Environment Laboratorios (SEPEL).
Inquiries should be sent to :

- Dr. R.J. DOWNS - North Carolina State University - Raleigh NC 27607
and
- Dr. H. HELLMERS - Duke University - Durham NC 27706.

D- Roundtable - Discussion (2 subjects)

1) International standards for measurement of the Environment.

Moderators : J. DOWNS (USA-Raleigh) and H. HELLMERS (USA-Duke).

The discussion showed a general need for better standardization of methods of environmental measurements.. An ad hoc committee was appointed to make recommendation (see later page 23).

2) Operation of the "Phytotronic Secretary's office" and the future of the "Phytotronic Newsletter".

Moderators : P. CHOUARD and N. DE BILDERLING (France - Gif-sur-Yvette)

a) The Phytotronic Secretary's office is not official. It was organized at Gif-sur-Yvette (France) after Professor F.W. Went's proposal at the Seattle meeting in 1969 to promote international meetings and to be an information centre and link between phytotronists. This work is voluntary.

b) Phytotronic Newsletters in 1964. The idea of a Phytotronic Newsletter was decided at London in 1964, at Seattle in1969 it was discussed again and its publication desired. At present two numbers have appeared : November 1971 and May 1972.

The purpose of these Newsletters is essentially to give information on international and national meetings and the ideas expressed there. It is quite different from a review in both conception and form. The idea of gratuity is very important in order to conserve the possibility objective's criticism with openings on all subjects of interest to the maximum number of readers.

The Actual diffusion is 1800 addresses : 1400 around the world and 400 in France. Each number costs about 2.000 FF (nearly 400 $ US) for stamps, paper, envelopes, stereotype plates and printing without any salaries or payment to staff (see Editorials and at the end : Next numbers).

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2nd Part - Examples of problems to which Phytotrons have made useful contributions.

A - Research on Specific Crop plants 1st sessior.. (6 lectures)

Chairman D. von WETTSTEIN (Danmark)

At the opening of the session, the chairman wrote on the black board : Phenotype = genotype + Environment. This emphasizes the role of environment from which one control their action by the population.

1) J.R. Mc WILLIAM (Australia) -- Adaptation to temperature stress in plants.

Many tropical and subtropical species are unable to grow and may be severely damaged by long exposure to low (chilling) temperatures in the range from 5-15°C. The existence of many annual and perennial representatives of tropical C4 genera in temperate environments suggests a degree of adaptive flexibility in such species which is under genetic control.

2) A. ULRICH (USA-Berkeley - Controlled environments in crop production research : sugarbeets, tomatoes and strawberries.

Night temperature, daylength, light intensity and nitrogen nutrition have important effects on the sucrose level in sugarbeets roots. For certain varieties of tomatoes nitrogen fertilization had the main effect. Light' intensity was the principal factor in the strawberry fruit and albinism was induced at low light intensity (1000 fc) and found to vary with variety.

3) D.P. ORNROD (Canada) - Responses of Pea Plants to temperature in controlled environments.

In pea plants the combination of high day (21°0 and night (16•C) temperatures caused an increase in the number of nodes to the first flower. Humidity has less influence and has no interaction with temperature. This delay in flowering was probably due to degeneration of the first flowers.

4) G. HOPSTRA, G.J.A. RYLE and R.F. WILLIAMS (Canada) - Effects of extend-in the day length with low intensity light on the growth of wheat and orchard grasses.

Extending the day length by very low light intensities produces an increase in day assimilation rate and a decrease in night respiration. of plants. The maximum photosynthesis is observed at 21°C day and 16°C night. Leaf growth is maximal at 15°C day and 10°C night. The starch concentration being variable, it would be interesting to control the CO_2 level.

5) G.J.A. RYLE E.L. LEAFS M.J. ROBSON and J. WOLEDGE (United Kingdom) -- Experimental research in controlled environments in relation to the perennial grass crops.

The comparison of the growth of perennial grass crops in the field using microcells for CO_2 analysis and the growth of identical plants in the controlled environment cabinets, provides a comprehensive picture of morphological changes and modifications in plant assimilation, which vary with the age and position of leaf. It is possible to determine how factors limit yield and begin to estimate the production.

6) B. BRETSCHNETDER-HERRMANT (Germany F.R.G.) - Growth development anal yield of different spring wheat varicties growth under field conditions and under different climatic conditions in the Phytotron day length-temperature trial).

The duration of vegetation was divided into S periods for the phytotronic study of wheat. We simulate two dry periods existing in Nature. This technique allows breeders to choose he varieties which will resist the natural conditions in our region.

2nd session (5 lectures). Chairman : J.L. APPLE (USA-Durham).

1) M.J. KASPERBAUER (USA-Kentucky) - Effect of pretransplant environment on post-transplant growth and development of tobacco.

A bad pretransplant treatment of plants can produce a too rapid floral induction in the post transplant plant. This effect can be counteracted by supplemental middle-of-night lighting or by an elevated temperature. Those results can be directly controlled and applied in practice.

2) B.S. VERGARA (Philippines) - Controlled environments in study of rice physiology.

The International Rice Research Institute (IRR1) needs a Phytotron to answer many questions about each selected or introduced variety in optimal temperatures for germination and anthesis, percentage of sterility in low temperatures, stem elongation, calcium deficiency under high temperatures, protein contents, photoperiodism etc. Research on these problems is necessary for better adaptability and for selection orientation.

3) P. De T. ALVIM, A.D. NrACHADO and F. VELLO (Brazil) - Ph siolo ical responses of the cacao to environmental factors.

Cacao tree seems to be sensible to °hydroperiodicity" which could cause large fluctuation in production. Temperature also plays a role. All these problems can be studied in environmentally controlled facilities.

4) U. MORENO (Peru) - Research in environmental. plant physiology without controlled environment equipment.

Potato plants were grown at three different regions of Peru. Tuberizetion and protein composition are different. Controlled environement equipment could solve more rapidly and economically all these problems.

5) C.A. FRANCIS (Colombia) - Effects of photoperiod and tern-peraturo on maize growth in the field in Colombia.

A number of inbred lines were insensitive to a change in photoperiod, while others were relatively sensitive. Tropical mate-rials tested were sensitive to extended days by incandescent light of low intensity (1-5 fc) while other West Indian composites and a temperate hybrid were insensitive. There is probably an interaction with temperature.

B - Use of Phytotrons in different disciplines,

a) 1st session (5 lectures). Chairman -.H.A. COLE (Sierra Leone).

1) J.A. TEERI (USA-Durham) - Field and Phytotron studies on the ecology of natural populations.

A study of population of Saxifrage oppositifolia L. in Phy-totron facilities shows many phenotypic difference, existing between distinct habitats more or less humid in the North Canadian Arctic, There are different levels of tolerance to humidity and variations in the functioning of photosynthetic systems and in the opening of sto-mata and therefore the transpiration rates.

2) F.E. ECKARDT (France) - Contributions of Phytotron research to the understanding of the functioning of photosynthctic systems in the natural environment.

Transparent controlled environment plant chambers were built in different sizes, with automatic control of temperature, humidity, and CO_2 content of the air and with also various micrometeorological features. Such chambers can be used in the field to study plant material : individual leaves, clusters of leaves, parts of plant, individual plants, plant stands, part of ecosystems etc. Mathematical analysis can provide models for the ecological studies.

3) W,W. HECK (USA-Raleigh) - Air pollution research on plants in Phytotrons.

Preliminary studies of ozone pollution on Pinto bean plants showed that the sensitivity was different according to duration of light and temperature. It seems that stomatal aperture plays an important role.

4) H. HELLMERS (USA-Durham) - Use of controlled environments in research in tree physiology.

The Phytotron. has made possible to study the basic physiology of trees and to select new species for introduction. IL can also provide for the reforestation of 1aarge burned areas by screening the best species for the region. But it is also an important tool for the study of the interaction of environmental factors and plant age which will provide a basis for predicting plant productivity in ecosystems.

5) C.E. MAIN (USA-Raleigh) - Use of Phytotrons for phytopathological research.

With adequate precautions to prevent contamination of other experiments, controlled environmental facilities provide an essential research tool in phytopathology. For exemple: epidotmiology, interaction between disease and climatic conditions, penetration, development and colonization of a population.

b) 2nd session (4 lectures). Chairman : G.V. THORNE (United Kingdom).

i) J. Mc NEIL (USA-Raleigh) - Role of four factors and their interactions, in diapause initiation of two hyperparasites of the tobacco hornworm, Manduca sexta L.

Insects exhibit frequently diapause in the prepupal and pupal stages. Studying hyperparasites it is necessary to find primary host, but frequently it also-has diapause which vary with different factors. For analysis of these interactions, it is necessary to use both a computer and controlled environments, without which it is impossible to have a complete study, since the interactions are frequently of the second or third degree.

2) F.C. STEWARD (USA-Cornell) - Environments, nutritions, metabolites, development.

There are multiple interactions between environmental factors and various crop plants. Multivariate experiments must be well prepared as well as the study of development and composition of the plants in question. It is necessary to use morphological and biochemical parameters as well as graphical means to summarize the results obtained.

3) J. HESKETH and H. HELLHERS (USA--Durham) - The use of controlled environment to develop computer models describing plant growth.

Development of a "degree-day" concept based on temperature controls of apparent plastochrons, organogenesis and time intervals between reproductive events.

4) R. SLATYER (Australia) - Brief observations on the symposium.

See later (page 15) the text sent by the author especially for the Phytotronic Newsletter.

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3rd Part .. Discussion of problems in the construction and operation of the Phytotron (6 lectures)

Chairman A.W. NAYLOR (USA-Durham)

1) T. SMITH (USA-Raleigh) - Maintenance operations of the SEPEL Laboratories.

Phytotrons must not have any break down, or interruptions. Therefore it is necessary to provide for an efficient maintenance at the time of its construction. It is necessary to have perfect flexibility and efficiency. Maintenance must be as easy as possible : accessibility, facitity of changes and modifications, eventually maintenance contracts.

2) T. MATSUI and H. EGCCHI (Japan) - Some problems in the analysis of the temperature effects on plant growth and differentiation, and automatic program regulation of plant growth by temperature control using a computer stem.

A micro thermister which was inserted into the cotvledon of Cucurbita maxima seedling reacts well to air temperature, relative humidity, light and air movement. Soil temperature remarkably affected the hypocotyl elongation. It is possible to develop a computer operated system, to control automatically the temperature and plant environment.

3) H.A. SENN (USA-Madison) - Operational experiences with the University of Wisconsin Biotron.

Description of Biotron with its 48 rooms for plants, animals and human beings. Chambers have different sizes, some of which are completely sound-proof. 2k hours technical performance. Scientists are accepted depending on the proposed scientific research.

4) S. RAJKI (Hungary) - The new Hungarian Phytotrron.

This Phytotron has 28 growth cabinets of different sizes. Open in 1972, it is principally intended for the study of vernalization of wheat by physiologists biochemists and genetists.

5) K.J. MITCHELL (New Zealand) - The new Phytotron in New Zealand.

2k rooms with very flexible conditioning of temperature, humidity, light intensity (attaining maximum summer sunlight), C02 concentration and mineral nutrition. Maximal automation and electronic controls. Central heating and cooling.

6) M. KONISKI (Japan) - Phytotrons in Japan.

After the first Phytotron built at 1953 at Mishima, several others installations have been built especially in agricultural faculties (air conditioned greenhouses, growth cabinets or Phytotrons). Since 1963 a Central Committee controls these installations. The construction of a National Biotron Center with 26 greenhouses and 100 rooms with artificial light and with maximal automatization is planned.

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Several documents were distributed to participants, the subjects of which were not retained for the symposium :

TEIJIRO TERAJIMA. Koito Industries, Ltd., Tokyo, Japan. Relation between design, temperature and humidity to air volume in Phytotron.

W.A. BAILEY, USDA, A.R.S., Agricultural Engineering Research Division, Beltsville, Maryland 20705. Optimizing the growth and development of horticultural plants in controlled environments : I. Environmental control in the phytoengineering laboratory.

D.T. KRIZEK, USDA, A.R.S., Plant Science Research Division, Beltsville, Maryland 20705. Optimizing the growth and development of horticultural plants in controlled environments : II. Physiological studies on whole plants.

H.H. KLUETER, USDA, A.R.S., Agricultural Engineering Research Division, Beltsville, Maryland 20705. Optimizing the growth and development of horticultural plants in controlled environments : III. Physiological studies on a single cucumber leaf.

B.K. HUANG. Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, North Carolina. Electronic circumference meter for continuous monitoring of plant growth.

T.W. TIBBITTS. Horticulture Department. University of Wisconsin, Madison, Wisconsin. Studying lettuce tipburn in controlled environments.

C. LOPEZ, Desert Research Institute, University of. Nevada, Reno. Nevada 89507. Effect of thermoperiod on the growth and morphology of Prosopsis tamarugo Phil. ("tamarugo") .

R.H. RODGSON, Plant Physiologist, Plant Science Research Division, ARS USDA, Metabolism and Radiation Research Laboratory, Fargo, North Dakota, Controlled environment and herbicide metabolism.

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III - BRIEF OBSERVATIONS ON THE SYMPOSIUM

Text sent by Professor R.O. SLATYER (Australia)

This meeting has probably been the first occasion where a group of scientists concerned specifically with the use of Phytotrons has been brought together to discuss all aspects of their use in biological research. In the process, the very nature of Phytotrons has been questioned, their limitations and advantages critically examined, and possibilities for extensions of their use explored. I hope the following brief and rather subjective notes provide a reasonable summary of these proceedings.

What is a Phytotron ? I think we have had a pretty broad range of definitions during this week, In fact, we have seen definitions of Phytotrons that range all the way from the single leaf cuvette, to the normal plant growth chamber, to greenhouses, and up into geographic regions. However, to most of us a Phytotron is typically an assemblage of rooms and greenhouses with a variety of controls, generally for regulating the flux density of total irradiance (and of photosynthetically active radiation), air temperature, and humidity. Such Phytotrons generally include fairly sophisticated control Systems and somewhat less sophisticated monitoring systems.

We need Phytotrons to control environmental variables. Under natural conditions the atmospheric and soil environment fluctuates continuously. Each of the component parameters interact and are not independent. For example, radiation and temperature are generally linked in nature ; photosynthetically active radiation and photoperiod are sometimes closely coupled. So, we need Phytotrons in order to use a classical strategy of experimental research ; that is, to control variables other than the one that happens to be of interest to us at any one time.

Limitations : Most Phytotrons have deficiencies. The main ones appear to be

1) The carbon dioxide level near the plant leaves is often unknown and is generally uncontrolled,

2) Irradiance levels are generally too low to permit light saturation of the photosynthetic apparatus, and much below natural sunlight.

3) Air flow rate may be too low to provide uniform air temperature, CO_2 and humidity levels.

4) Humidity control is often inadequate, also absolute humidity is seldom controlled. Since we are generally concerned with a parameter related to the evaporative demand, an absolute water content parameter is more appropriate for control purposes than relative humidity.

5) Cabinets may be too small, so that edge effects may cause differences in performance at different points within cabinets,

6) The root environment is seldom controlled. Root temperature and seal, or substrate, water status are the most important parameters affecting plant growth and development.

7) There are inadequate opportunities for studying the interaction of plants with other organisms.

Apart from these specific deficiencies, which may apply to a greater or less extent to different Phytotron.s, the maine research limitation of phytotrons is probably that of environmental constancy, within any one treatment. In the field there are problems of variability from continually fluctuating environmental conditions. In the Phytotron, the control of the environment creates problems of extrapolation to natural conditions. This is why Phytotrons can only be tools in biological research. When we use Phytotrons, we are essentially looking at physiological processes rather than at ecological or agronomic phenomena in a direct way. It is always important to remember that the organist., we are examining is the phenotype we produce in the Phytotron, not the phenotype that we produce out of doors.

Sometimes the point gets raised that in very few Phytotrons is there an attempt to simulate the natural environment. My main reaction to this subject is -Why try ? Let's use the Phytotron to control parameters deliberately rather than trying to simulate a natural environment. One might ask why have a Phytotron if the main objective is to create a natural. environment inside it?

Advantages : The main advantages of Phytotrons that, have been brought out reflect, in particular, the ability to examine the effects of specific environmental factors on specific physiological processes.

This is something which we cannot do in any other way. We also have had evidence during the meeting that Phytotrons permit substantially reduced replication in biological experimentation because of the ability to reproduce uniform material both in time and in space, but let me add the qualification that this must be checked and rechecked - it cannot be assumed.

Opportunities : What are some of the opportunities, provided by Phytotrons, which may not yet be fully utilised in research programs ?

I think one research area which could be much more fully explored concerns the environmental physiology of development. Specifically, this could involve looking at morphogenesis at all levels from cellular to whole plant. Gaps in our knowledge in this area have been high-lighted by some of the first attempts at modelling plant production. These models have used very crude functions to partition, for example, photosynthate between leaf, stem. and root ; and very crude models to partition photosynthate between biological and economic yield. Under controlled conditions, we can discover exactly where the products of photosynthesis go and hot; morphogenesis is affected by specific environmental factors.

A related subject matter area concerns the development of models for predicting the growth and production of plants in Phytotrons themselves. At present, models being derived for real plant communities, based on measurements made out of doors, encounter all sorts of problems because of the variability of the natural environment, These problems make it very difficult to progress in a rigorous and definite manner, even though ultimately it has to be done with field data. The development of models which describe how plants grow in Phytotrons, even though. they apply to that phenotype rather than the one we have, in the field, provides the opportunity to investigate the specific response surfaces that need to be collected for field models and in some cases may provide first order estimates of those response surfaces.

A second area in which Phytotron research provides substantial opportunities is that of acclimation and adaptation. We know from various sources of evidence that plants grown at, say, 20°C will tend to show peak photosynthetic performance at 20'C, or very close to it, even though their normal growth temperature might be different. We know that plants subjected to several days of cloudy weather will respond differently on the next day of sunny weather than plants which have been exposed to sunny weather throughout.

There are a whole range of factors associated with acclimation of plaints to changing environmental conditions which tend to be rather bewildering when they are encountered in the field. The Phytotron is well suited to the exploration of the physiological processes which underlie these phenomena.

Thirdly, I think we can extend one, of traditional uses of Phytotrons : that of screening plant material for special phenological features. Jointly with plant breeders this has been a profitable area of research in agronomy and in the development of plants which perform well in particular environments. Species with specific thermal or photoperiod requirements appear to have particular promise: in this regard.

Closely related to screening is the opportunity to find plants which will perform differently under conditions other than those where they now grow naturally. One only has to see the performance of Monterey Pine (Pinus radiata) in sown forests in Australia and compa.re it wish its appearance on the Monterey Peninsula to realise that this potential could perhaps have been found out in a Phytotrcn. There may be a large number of species which, in their present environments, are biogeographical relics no longer growing in a favourable environment.

Other opportunities for experimentation exist by remedying some of the deficiencies in existing Phytotrons that were mentioned earlier. In this respect, I would regard the deliberate control of the root environment as an important cnvironmental variable to incorporate in Phytotron experiments. I really do feel, that this is a substantial area of neglect of many of us, and I include myself in this criticism. I think that we have been reluctant to perturb and control the root environment in the way that we have treated the serial environment. Root temperature, water status and aeration are of particular importance. Nutrient--root environment interactions also offer much scope for exploration.

A final area of study which I think should be emphasised, concerns the use of organisms other than plants. In nature we know that plants don't grew in isolation. As we turn our minds more and more to how whole ecosystems work, and become more preoccupied with the tropic interlaces that develop in ecological systems, the more we are going to be aware that there are opportunities in Phytotrons to introduce deliberately some of these factors as experimental variables. The conference has provided examples of studies involving plant-insect and plant-pathogen interactions. I think that controlled environment facilities for higher plants lend themselves to this sort or research and may be a way in whicb some real progress could be made in understanding how natural ecosystems work.

Additional requirements for effective Phytotron research: I think that, during our deliberations, three areas of additional requirements have come to the surface.

The first has been to do with technical needs. In general hotter control and monitoring of atmospheric carbon dioxide and atmospheric humidity seem to be needed. This will probably- require different sensors and may also require different air flow characteristics. Better control of water status is also needed, despite the problem in providing different levels of stress. I wish I could suggest a series of methods of turning water stress on and off in the way one can turn temperature on and off. Unfortunately, it is a much more dynamic Parameter, as those of us concerned with it know. But apart from the problem of imposing different degrees of water status, we do, I believe, have watering procedures in many Phytotrons which are inadequate to ensure that water stress is avoided.

The conference has also highlighted the opportunities for using Phytotrons to study the effect of various environmental pollutants on plant performance. Clearly the introduction of these pollutants as experimental variables will need to be associated with a relevant technology for treatment imposition, control and monitoring.

Secondly, there are experimental needs : in particular I think we need to select projects for Phytotron research which are capable of effective solution. In other words, we need to ask questions that can be answered in Phytotrons. Sometimes I think we begin Phytotron experimentation expecting that the very general questions we might be pursuing will, in some mystic way, produce meaningful results. I suppose they usually produce publishable results but I believe we should be more critical about the sorts of questions we ask and might ensure that the treatments that we apply will enable valid results to be obtained from the responses that occur.

In this regard, I think that rate of onset of stress, the degree and duration of stress and the rate of removal of stress in experiments that involve temperature, treatments, water stress or radiation treatments, need to be carefully considered.

Associated with this requirement., is a need to provide good dcscription of what is done in any particular Phytotron experiment, despite the fact that biological journals are reluctant to publish extensive descriptions of methodology, It is vitally important to other investigators to know exactly how experiments were done.

One other experimental need deserves mention. I think we should recognize that stomata can frequently mediate the responses that we observe in plants. This is something that I am perhaps particularly sensitive about but a number of other people al. this meeting have raised this point. If we wish to look at a physiological process that is influenced by a stotnatal response, it. is most important for us to take care of the stomatal response itself so that we can look directly at other response.

Apart from these technical and experimental needs, the other subject that arose in terms of additional needs ,as the general ques-- tion of international standards for environmental measurements. Clearly, standards are desirable but I think it is more important that the sensing instrumentation and their characteristics are clearly specified in experimental descriptions. However, I am glad that we have set up a committee. I think that with the information that is already available through international agencies, such as the World Meteorological Organization, it should not be difficult for us to reach Acceptable standards for measurements and, hopefully, in many cases for sensors also.

The need for a Phytotron newsletter has also been raised on a number of occasions. I think there has been general agreement that it can be very useful for people working in Phytotrons to be aware of what is going on elsewhere, but there seems to be a lack of consensus on how elaborate it should be. For many people, a simple list of investigators and project's in each Phytotron may suffice.

<u>Conclusions</u> : It is difficult to draw these discussions together in terms of clear cut conclusions, but tile following main points

do appear to have emerged

1) Most Phytotrons have several technical limitations in the degree of control they exert over any environmental variables, In most instances these deficiencies can be remedied with existing technology-.

2) Phytotrons are powerful tools in biological research. However, f'or meaninful Phytotron experimentationi, it is essential that questions be asked that are amenable to Phytotron experimentation, and that experiments be imposed which will enable experiments to provide proper answers.

3) Since a phenotype is a function. of genotype and environ-- merrt:, plants grown in Phytotron should not be expected to resemble plants grown in natural environments, either in appearance or in physiological response, Rather than simulating the natural environment the Phytotron provides the opportunity to control environmental variables independently and thus understand the Characteristics of the phenotypes Hereby produced.

14) Phvtotrons can be used effectively to study physiological processes that underlie ecological phenomena, but it is. doubtful if they can be used to study ecological phenomena directly. When Phytotron studies are used to complement field studies they can play a very valuable role in ecological investigations.

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IV - CONCLUSIONS AND LESSONS DRAWN FROM THIS SYMPOSIUM

Part or the text sent by the organiser Prof. P.J. KEAMER (USA-Duke)

for the Phytotronic Newsletter.

The time seems to have been ripe for this conference. Extensive use of controlled environment equipment during recent years has, pro- vided many examples of the kind of research which can be done in them. Experience also is beginning to show clearly these features of' growth chambers and phytotrons which need to be improved. As a result there was frank and lively discussion culminating in general agreement on the need for certain improvements which will be mentioned later. There was a notable desire to improve the methods for measuring and reporting data on environmental factors. It seems likely that there will be significant improvements in existing and future controlled environment Facilities as a result of this symposium.

Among the topies discussed , the following seemed most important to the improvement of research in controlled environments.

1 . There was serious consideration of how to correlate field and Phytotron research to increase the overall effectiveness of rese- arch programs. Useful illustrations were given by several speakers of how a combination of the two kinds of research were used to identify the nature of a variety of problems and to Solve some of them.

2. For the first time in our knowledge a careful study was presented showing Cho relative costs of field and Phytotron research. This study, based on research on tobacco at North Carolina State University, indicates that where labor costs are high, Phytotron research often is considerably 1ess expensive than field expcriments. This is because the smaller number of plants required per sample in the Phytotron than in the field greatly reduces the cost of laboratory work. The more high cost labor used the greater the economy of Phytotron research over field research. The figures presented did not take into account the hazards from insects, diseases, and unfavorable Weather which sometimes ruin field experiments. SuCh accidents sometimes require that field experiments be repeated another year, delay-- ing results and adding to their cost.

This kind of information should be useful to administrators and granting agencies who must balance the cost of controlled environment facilities against their benefits. It also will be useful in deciding whether a particular experiment should be done in the field or the Phytotron where such alternatives exist.

In this connection it should be noted that there was general agreement that use of controlled environment facilities is critical for some purposes, such as study of response of plants to various environmental factors. Several speakers pointed out that they found it practically impossible to separate the effects of various rapidly varying environmental factors in the field, but they were able to do so in controlled environment facilities. Considerable evidence was presented indicating that the most valuable results often are obtained by a judicious combination of field and Phytotron research.

3. An ad hoc committee was appointed with P. Gaastra of The Netherlands as chairman, to develop practical methods for uniform measuring and reporting of the environmental parameters in controlled environment facilities. This problem has been discussed at various conferences over t.nce past decade and is no,, being worked or, by committees appointed by various organizations. However, no really practical recommendations have become available to operators of controlled environment facilities. It is hoped that the ad hoc committee established at this meeting can produce some practical recommendations which wi11 enable investigators from all over the world to report environmental conditions used by them in a manner that permits comparisons. The most pressing need is for a relatively simple, inexpensive device to measure the quantity and duality of radiation in a generally acceptable manner.

4. There was considerable discussion of the improvements needed in much of our controlled environment equipment. These include better monitoring and control of carbon dioxide, better control of water supply to plants, separate control of root and shoot temperatures, more rapid air movement, and more attention to humidity control. The latter should be based on absolute humidity or dew point, rather than on relative humidity. Slatyer suggested that for some ecological studies we might to be able to permit interaction of plant with other organisms This is possible in some facilities (e.g. Madison).

3. There was some discussion concerning the philosophy behind the operation of a Phytotron. Several speakers referred to it simply as a tool to be used in solving problems on the interaction of plants

and their environment. However, van Davol suggested that Phytotrons, like nuclear accelerators, ought to have a staff of scientists attached to them to make broad, coordinated studies of various aspects of plant growth. This idea also was advanced by F.C. Steward who pointed out that we usually obtain only a small part of the data which is available from plants grown in controlled environment experiments. There is no doubt that such an approach would be very profitable, but. it would require the cooperative efforts of several societies.

It would not necessary interfere with the use of the Phytotrons by other investigators to solve various specific problems.

6. Another interesting and important question concerns the objectives of Phytotrons. Should they attempt to simulate the natural environment or should they be content to provide standard reproducible environments? Most users have assumed that constancy of environment is more important than simulation of outdoor environments. Constancy and reproducibility are certainly the first requirements of controlled environment equipment however. van Bavcl and Mitchell seem to be aiming at levels of radiation, humidity, and air movement comparable to those occurring in the open, The importance of simulation of open air conditions probably depends on the objectives of the investigators.

Related to the problem of simulating "natural" conditions is that of producing "normal" plants. Mitchell stated that their primary objective is to grow plants comparable to those grown in the open, presumable under favorable conditions. However, much of the research in controlled environment facilities deals with study of effects of different, levels of various factors on plant growth and this naturally results in such subnormal growth. Since the principal objective under these conditions is to compare rates of growth, flowering, and other physiological, processes, the exact growth status of the so-ca]led controls is probably less important than the differences among the treatments.

There also is some question concerning what constitutes a "normal" plant. A commercially satisfactory tobacco plant should be nitrogen deficiency and chlorotic as it approaches maturity and a really healthy tobacco plant is totally unacceptable to cigarette manufacturers.

However, some attention to the general level of growth certainly is necessary and this has led a group of horticulturists to consider the possibility of describing a "standard" plant. Apparently the idea is to produce a description of the amount and kind of growth which ought to be produced in a growth chamber of minimum acceptable performance.

In summary, the most important resu1t of this symposium appear to be the following.

1. A better appreciation of the wide variety of research which can he aided by the use of a large Phytotron.

2. Improved understanding of the levels of various environmental factors which need to be maintained in controlled environment facilities.

3. General realization of the need for improvement in measuring and reporting the levels of various environmental factors.

In general participants in this Symposium went home with a better understanding of how to use Phytotrons and plant growth chambers more effectively in their resea.rch,

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V – COMMITTEE FOR THE STANDARDIZATION' OF MEASUREMENTS OF ENVIRONMENTAL FACTORS IN PHYTOTRONS.

by Dr. P. GAASTRA (Ne LILcri ands)

During the Symposium an evening session was devoted to a discussion of international standards for measurement of environmental factors.

The discussion showed that among “phytotronists,” more standardization is desired on :

a) The selection of the environmental factors measured or described.

b) The methods applied in the measurements.

c) The units in which the measured quantities are expressed.

The selection of relevant factors and the use of comparable methods and units will improve the value of experimental results as well as reproducibility of results obtained in different Phytotrons.

An Executive Committee was nominated to formulate recommendations on methods and units. Methodical procedures proposed previously by meteorological raid other organizations, will be incorporated whenever possible. In this way it is expected that recommendations can be made within about one year. The Committee will consider also ways in which recommendations ultimately could be implemented, for example through international scientific organizations or editorial boards of scientific journals.

Members of the Committee are:

Dr. P. Gaastra, Centre for Plant physiological Research, Wageningen, Netherlands (chairman),

Dr. D. Koller, Department of Agricultural Botany, Hebrew University of Jerusalem, Rehovot, Israel,

Dr. M.Konishi, Faculty- of Agriculture, Kyoto University-, Kyoto, Japan,

Dr. K.J, Mitchell, Plant Physiology Division (DSIR), Palmerston North New Zealand,

Dr, G. Thorne, Department of Botany, Rolhausted Experimental Station, Harpenden, Great Britain,

Dr. C.H.M. van Bavel, Texas A & M, College Station, Texas, USA.

It is planned to enlarge this committee with members from other countries where which have Phytotrons. New members who gave their acceptance :

Dr. R. Jacques, Phytotron, CNRS, 19190 Gif-sur-Yvette, France.

Dr. Ju.N. Philipovsky, Inst. Plant Physiology Ac. Sc. Leninsky Prospect 33, Moscow B-71 USSR.

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VI - COMMUNICATIONS AND INFORMATION FOR. PHYTOTRONISTS.

a) New books.

1) Phytotronique et Prospective Horticole. Review of lectures and discussions during the symposium organized on the occasion of the 18th International Congress of Horticulture - Tel Aviv, Israel. Ed. Gauthier-Villars, 55 quai des Grand* Augustins Paris 70 - 408 pp. 108 figures, 47 tables. Price : 140 FF.

2) Lighting for plant growth by L.D. Bickford and S. Dunn. Ed. The Kent Stale University Press-Kent-Ohio 44242 USA. 222 Pages, figures, references, index. Price : 16 $.

3) Growelectric-Handbook n° 1 - Growing Rooms. Ed. The Electricity Council - 30 Millbank -- London SWIP - RD. United Kingdon (Mr. J. Weir). 72 pages, 35 figures, 5 appendix, Price : 50 pences.

4) Theoretical foundations of the Photosynthetic Productivity. Conferences and discussions during the International Symposium "Productivity of Photosynthetic Systems" Part lI - Moscow 23-29 Septeriber 1969 (In Russian). Ed, Nauka-Moscow, 546 pages, Price 2,5G Roubles.

5) Phytotron5 and growth-cabinets in Japan. (In English). Ed. Japanese Society of Environment Control in Biology. Dr. M. Konishi- Laboratory of Applied Botany - Faculty of Agriculture Kyoto - 'University - Japan.

b) Japanese Journal.

Japanese colleagues announce that the Japanese journal : Environment Control in Biology published since 1964 4 numeros a year will print contributions from abroad. Until 1970 all papers were in Japanese. Since then, all articles have an English summary and papers will now be published completely in English. Probably in a few years, the entire Journal will be published in English. Address of this Journal : Japanese Society of Environment Control in Biology,--. The University of Tokyo Press Tokyo Japan.

c) Announced meetings:

1) 1973 - Two meetings will be organised jointly with the International Society for Horticultural Science (ISHS) :

- Cultiyation under protection in the Mediterranean regions.

25-28 April 1973 at Barcelona, Spain. Topics : Cultivation of flowers under shelter. Organizer : Dr. J. Cccrdus 1.N.T-A. Estacion do Floricultura - Cabri.l.s - Barcelona, .Slain,

29 April - 1st May 1973. Excursion between two symposia : Costa Brava. Alenva Station near Perpignan and Technical visits or greenhouses.

2-5 May 1973 at Avignon France:. 'Topics : Cultivation of vegetables without shelter. Organizer : Dr. P. Pecaut, I\'RA - Station drAmelioration des Piasttes haraicheres, Dorraine Sainl. Maurice - 84 140 Mont favet-Avignon - Francc.

- Greenhouse Design and Environment.

To be held at the National College of Agricultural Engineering, Silsae, Bedfordshire, England. From 1P-2O Sel.teuber 15 73. Organizer: A.E. Caniiura. L'e art;sent of Horticulture - ARS- Shinl'icld Green - Reading RG 2- 913E -U.K.

2) 1574. Watrsow, , 11-18 September.

XIX Ca International Horticultural Congress with 8 different section:, In the first general section there will be a special session No 7 Phytotrons in Horticultural. Research.

Organizing work for this session will be done by our Phytotronic

Secre tary''s office. We shall give you in the next phytotronic Newsletter more practical details about contributing papers of a 10 Minute time 1enght.

3) 1975 Two meetings will be organized

USSR, Leningrad. In September 1975 during the International Congress of Botany, academician M. Nil. Chailakhyan plans to organize a symposium on the topics "Growth and development_of plants in controlled environment".

Japan – Kyushu and Kyoto. Before or after tha Botanical Congress, the Japanese Society of Environmental Control in Biology is planning to hold an International symposium or congress on biotrons or biotronics.

d) Future numbers of Phytotronic Newsletters.

As well as descriptions of scientific meetings on Phytotronic problems, several readers have given us suggestions for for other interresting subjects. We also would appreciate voluntary contributions, notes or texts in French or in English which we shall try to print as soon as possible. For the moment we have the following subjects on which we are trying to gather material-, or infornation:

- reference list of home-made rooms or controlled environment cabinets.
- information from installators and builders of air conditioning in greenhouses.
- research strategy of existing Phytotrons.

- programs and results of research in the main agricultural, horticultural or university Centers.

Our bulletin of information and connections can not be really efficient' without a collective work. Our role at the Phytotron of Gif is to receive, to classify and to publish what any of our readers thinks would be useful for others to know : conference, svm` osiums (announced or described) technical new inventions, books appeared or in preparation with address of publisher, personal meditations etc...

Nevertheless it is necessary to look higher and farther ahead the general opinion, amongst biologists, is beginning to consider Phytotrons and phytrotronic equipment as tool, capable of giving a physiological meaning, i.e. functional, to ecological, biophysical or biochemical research. They lead to the expression of new concepts, some of which must be generators of practical applications.

To stimulate our thoughts and activities in this way, we think that it is better to help us to publish in every number of "Phytotronic newsletter" some specific examples of what one can accomplish with Phytotronic equipment. We should like to receive a summary, in a few pages, of examples of research strategy fulfilled with the help of the phytotronic method, which will be published here ; these concrete cases would be stimulating for us all.

Thank you for your cooperation,.

P. Chouard and X. de Bilderling.