

PHYTOTRONIC NEWSLETTER N° 18

Contents

	Pages
I. Editorial	1
<u>Annual Reports-Research Strategy</u>	
II. Phytotron. North Carolina State University 1976. Annual Report	2
III. Duke University Phytotron. Annual Report 1976	9
IV. K.A.TIMIRIAZEV Institute of Plant Physiology (Moscow, USSR) Prof.B.P.STRO- GONOV and Dr.V.I.KEFELI	14
V. Current plant biology research at Biotron University of Wisconsin (USA) T.T.KOZLOWSKI	25
VI. The Plant growth rooms at the Department of Plant Husbandry. Uppsala (Sweden) .U.WUNSCHÉ	35
VII.LIB Laboratory at Essen (F.R.G.)	51
<u>Articles and Scientific papers</u>	
VIII. The plant Gnotobiology Laboratory; description, procedures and uses. N.HOPKINS and M.HALE (USA)	58
IX. Controlled Environment facilities and their use at the Glasshouse Crops Research Institute. Littlehampton. B.ACOCK and R.G.HURD (UK)	64
X. Revised Guidelines for reporting studies in Controlled Environment Chambers ASHS Special Committee on Growth Chambers Environments (USA)	67
XI. Dynamic Modeling of Glasshouse climate and the application to glasshouse Control. G.P.A.BOT and all.(The Netherlands)	70
XII. Differences in Response of plants grown under controlled conditions and in the field. J.E.BEGG (Australia)	81

	Pages
HIII. Problems of growth analysis in controlled environments H.KRUG (Germany FR)	84
HIV. Potato Tuberization studies in controlled Environments. P.S.HAMMES (Rep. South Africa)	89
XV. Life History as related to weed control in the Northeast.N° 8 Common Rag-weed (USA)	92
WVI. Hydraulic Architecture of Trees. Summary of Dr. M.H.ZIMMERMANN conference (USA)	97
XVII. Contaminants in plant growth chambers A.S.H.S. Growth Chamber Committee (USA)	101
XVIII. Simplifying the lamp changing schedule in Phytotron with the Help of a computer program R.C.HARDWICK and D.J.ANDREWS (UK)	103
<u>News and Miscellaneous information</u>	
XIX. Controlled Environments Working Conference March 1979 Madison (USA)	104
XX. Climate Laboratory Newsletter n ° 9	104
XXI. ESNA Report, 15 November 1977 and Newsletter	108
XXII. List of New Books	111
XXIII. Articles in print	113
XXIV. Coming events, Meetings and exhibitions	116

I.EDITORIAL

Publication of the 17th issue of the PHYTOTRONIC NEWSLETTER had been unduly delayed due to difficulties, which were mainly of a financial nature.

We were able to distribute it, as well as the present issue, however, thanks to a special grant from the Directors of the C.N.R.S. (National Center for Scientific Research). To all those responsible for having helped us solve these problems so effectively we send our sincere thanks.

x

For our part we hope that our readers will kindly excuse the unintentional delays in the distribution of these issues.

x

Our thanks above all to the many people who have shown their interest in the continued publication of the PHYTOTRONIC NEWSLETTERS. We ask that they understand that, due to secretarial difficulties, we are frequently unable to reply to their letters.

We also thank all those who have sent us benevolent financial aid. As always, we ask you to send your donations to our intermediary with the endorsement: "Participation aux frais de parution de "Phytotronic Newsletter"" and making cheques payable to:

"Agent Comptable secondaire du CNRS-4eme circonscription
91190-Gif-sur-Yvette, France".

Postal cheques or money orders are payable to:

"Agent Comptable Secondaire du CNRS-4eme circonscription
CCP Paris 913848 U Paris".

x

The contents of this issue are comprised, as usual, of several chapters:

a)Meetings-In this issue we have left out all reports, due to lack of news, on the one hand, and due to an abundance of other news, on the other hand. Those desiring to obtain more information should refer to the paragraphs dealing with meetings and with the necessary addresses.

b) Research plans, Phytotron and Laboratory activity

This is a voluminous chapter and comprises reviews of research done **in** several centers: 4 in the United States (Raleigh, Durham, Madison and Blacksburg), the USSR at the Timiriazev Institute in Moscow, Uppsala in Sweden, Essen in the Federal Republic of Germany and Littlehampton in Great Britain. We thought that it would be useful to inform our readers of the organization and research carried out in these centers.

c) Articles and scientific papers -The papers cover diverse subjects: modelization , programming techniques, analysis of plant growth in controlled environment and in natural environment, risks of pollution in growth chambers. The varied topics covered will allow our readers to find one of interest to them.

d) Recent events and other news. This last chapter is usually greatly appreciated by our readers, judging from the letters we received. We would like, however, to be kept informed of those events or meetings likely to interest other readers.

x

In conclusion, we ask our readers to send us scientific and technical literature, articles, news, applied or fundamental research papers in plant physiology and horticulture which might interest "phytotronists". Thanking you in advance, we send you our best wishes.

R.Jacques and N.de Bilderling.

x

[II. PHYTOTRON.NORTH CAROLINA STATE UNIVERSITY 1976. ANNUAL REPORT
--

Editorial Note: The Director of the Phytotron in Raleigh, Dr. R.J.DOWNS, has kindly sent us his 1976 Annual Report which comprises 115 pages. In spite of the delay in publication, we have here extracted some paragraphs which may be of particular interest to our readers. Those desiring other or more precise information should contact: Dr.R.J.DOWNS, SEPEL, North Carolina State University, Raleigh NC 27607, USA.

THE SOUTHEASTERN PLANT ENVIRONMENT LABORATORIES

The Southeastern Plant Environment Laboratories have been described in detail several times. Briefly, SEPEL consists of two Phytotrons, one at Duke University and one at North Carolina State University. The Phytotrons, supported by the cooperating Universities, the N.C. Agricultural Experiment Station and the National Science Foundation, compose a regional facility available to all biologists who need controlled-environmental conditions to carry out their research programs.

Characteristics of the Southeastern Plant Environment Laboratories (SEPEL)

	NCSU	Duke
Building area	3922 m ²	3192 m ²
Building volume	18589 m ³	15175 m ³
Electrical supply	480/277 V, 3 ph y - connected	
Present connected load	2240 KVA	1810 KVA
Possible connected load	3000 KVA	2000 KVA
Refrigeration		
Chilled water	3720 MBH	2809 MBH
Ethylene glycol	3053 MBH	1526 MBH
Controlled environment rooms		
Greenhouses 6.7 x 7.3 m	3	6
Cooling	360 MBH	360 MBH
Lights	Photoperiod control both units	
A-chambers 2.44 x 3.66 m	22	8 light 2 dark
Cooling	87 MBH	87 MBH
Fluorescent lamps	18060 W	18060 W
Incandescent lamps	4800 W	4800 W
B-chambers 1.22 x 2.44	10	10
Cooling	40 MBH	40 MBH
Fluorescent lamps	6020 W	6020 W
Incandescent lamps	2400 W	2400 W
C-chambers 0.91 x 1.22 m	20	20
Cooling	6 to 9 MBH	6 to 9 MBH
Fluorescent lamps	1600 W	1600 W
Incandescent lamps	600 W	600 W
Anterooms	4	4
Seed Germinators	12	
	No load data	
Incubators	2	
Cooling	6 MBH	
Dew chambers	2	
Cooling	6 MBH	
Air pollution treatment rooms	4	
Photoperiod rooms	9	

Note: MBH is thousands of British Thermal Units per hour 1 MBH = 252 cal. Kg-1 = 8.33 x 10⁻² tons of refrigeration (U.S. comm.).

NEWS FACILITIES AND MODIFICATIONS

The SEPEL Phytotrons are dynamic facilities in which the various components are constantly being evaluated and redesigned for improved performance and reliability. Existing equipment may be modified and new apparatus constructed to meet the ever-varying demands of biological research. Of current interest are atmosphere control, root environment, long and short wavelength radiation and, of course, solar energy.

A)Computerization of the Phytotron. Data acquisition and process control are daily operations in Phytotrons. Usually environmental factors are controlled independently, environmental data recorded on several separate instruments and information on biological response, biochemical changes, etc. logged manually. It is this latter limitation-the inability to record most biological data automatically and continuously-that seriously restricts the usefulness of data processing equipment in Phytotron operations. (It should be noted that a computer terminal as well as a programmable calculator is located in the Phytotron for use by investigators in processing their data).

The microprocessor, however, is an ideal hard-wired logic replacement element. Consequently, we are developing a microprocessor dedicated control system for all timing functions in the Phytotron. The first unit is now in operation for testing. The design is based on the premise that in the future we will want to add readouts for the various environmental factors, alarm-limits, and set point control. Ultimately the chambers can be completely programmed by the microprocessor.

b) Air Pollution Research Laboratory. This laboratory contains four, temperature and humidity controlled, gas-tight treatment roomettes designed as continuously stirred tank reactors (CSTR). They are lighted by high intensity discharge lamps of the metal halide type. These units, developed by W.W.HECK'S research group, were modified by adding reflecting walls, insulation and radiant heat absorbers in order to extend the temperature range and provide higher quantum flux densities of photosynthetically active radiation (PAR).

A dual CSTR designed by Hugo ROGERS for use in controlled-environment rooms was brought into the Phytotron late this year. These units will be used to determine uptake rates of NH_3 and to follow the fate of NH_3 as a plant metabolite. Researchers may also work with NO_2 , NO , and SO_2

c) Automatic Watering: We have always supplied automatic watering on an individual basis but now programmed water and nutrient solution application are available as a standard cultural practice. Evaluation of a number of spitters, drippers and emitters allowed us to select the type that produced the most uniform flow with the least tendency to siphon. We are currently changing our manifold design to facilitate hook-ups.

The programmer now in use allows a selection of 6 on-times by moving a pin jack. The range of the on-times can be altered and they can be cycled from every 5 minutes to once in 24 hours. A greater flexibility will result when the system is added to our microprocessor controller.

d) Photoperiod Rooms: The temperature-controlled photoperiod rooms were described in the 1975 Annual Report. Three additional, somewhat larger ones, are nearly completed. During the growing season these rooms can be operated on natural photoperiods and we can set up systems to program growing-season photoperiods from any latitude.

e) Reach-in (C-type) Chambers: One of the more critical to the research programs, is the vibration from the refrigeration system that is transmitted to the chamber frame, and consequently to the biological material. Although such vibration is characteristic of reach-in controlled environment chambers many researchers have objected to it.

f) Carbon Dioxide Control. Our CO_2 control system has been in operation for several years. It has worked so well that only minor changes have been made; such as more efficient means of removing moisture from the air sample. We recently installed a 4-tank manifold to improve supply reliability.

g)Lamp Loft Barrier: We are in the process of evaluating barrier materials other than the traditional clear plexiglass. These include double-layer material such as CY/RO acrylite SDP and Kalwall panels, as well as thin film plastics. More important to the Phytotron user, we are redesigning the method of barrier installation to allow access to the lighting devices without moving or disturbing the biological material.

h)Root Temperature Control: It is generally agreed that precise root temperature control over a moderately wide range should be available for at least some kinds of Phytotron research.

C.D.RAPER, Jr. and his coworkers E. YORK and W.UYTERHOEVEN have designed and built a continuous flow, liquid culture system that provides independent control of root temperature. Developed for use in the Phytotron, one set is now in operation to provide three different root temperatures. More of these will be constructed as demand indicates.

ACTUAL RESEARCH

Phytotrons are designed for whole plant or organismal research. Consequently, they are rarely used in biochemical research where plant materials are quite often purchased in the local supermarket. If this is because the biochemically oriented plant scientists do not have the facilities to grow satisfactory plants, then more biochemistry will surely be done in Phytotrons when it becomes known that the staff can grow all the plant material. Research in the NCSU Phytotron often includes analyses of biochemical components. Soluble carbohydrate, nitrate and organic nitrogen are regularly included in the data. Nitrogen reductase and glutamate dehydrogenase activity, ATPase, adenosine phosphates and phosphate dehydrogenases as well as fatty acid and amino acid composition have been part of various investigations. This is not "pure" biochemistry but is part of the metabolic response of plants to environmental stress. As a result such research is reported under appropriate headings such as germination, physiology, tissue culture and air pollution.

The NCSU Phytotron operates around whatever research program the investigator wishes to conduct. Therefore the research is very diverse, including circadian rhythms, diapause, amino acid composition as affected by temperature and studies in epidemiology. The physiology of flowering has been an area of particular interest and has involved growth regulators, nutrition, and of course, various environmental factors.

Auxiliary facilities for air pollutant research, tissue culture and mathematical modeling have resulted in some emphasis in these areas of study. The air pollution laboratory, headed by W.W.HECK, contains the essential equipment and instrumentation for use and measurement of phytotoxic gases. Areas of interest include the influence of air pollutants on Rhizobium activity and N-fixation and the physiological and biochemical changes resulting from climate-induced sensitivity to air pollutant chemicals.

The tissue culture laboratory, headed by R.L.MOTT, is equipped to prepare a wide variety of sterile cultures. Phytotron experiments have emphasized evaluation of genotypes and environments for adventitious bud induction from embryos as well as the effects of substrate composition and environment on subsequent growth and differentiation. Present work is aimed at defining the role of environment at the different morphogenic stages and to arrive at some conclusion as to why the genus Pinus seems to be unique in having strict environmental requirements for each of these morphogenic events.

The mathematical modeling programs have benefited from the versatile computer network offered by the Triangle Universities Computer Center and by the cooperative efforts of the Biomathematics department. Dynamic models are being developed for tobacco, soybean, peanut and bushbean. Such models are an important part of stress physiology research because the normal or healthy growth model is obviously necessary in order to understand the effects of stress.

a) Pollution atmospherique. Air Pollution Research

W.W.RECK, J.A.DUNNING and H.H.ROGERS. Uses of the Phytotron to study the effects of air pollution on plants.

J.A.DUNNING. Relative humidity affects the response on oat exposed to sulfur dioxide.

A.S.HEAGLE. Effect of ozone on parasitism of corn by *Helminthosporium maydis*.

R.B.PHILBECK. A plant exposure system for atmospheric pollution research.

U.BLUM and D.T.TINGEY. A study of the potential ways by which ozone could reduce root growth and nodulation of soybean.

M.B.LETCHWORTH and U.BLUM. Effects of acute ozone exposure on growth, nodulation and nitrogen content of ladino clover.

R.A.REINERT. Effect of temperature and O₃ on the Early growth of tomato, pepper and marigold.

D.N.ROSS. The effects of O₃ and ancymidol on three cultivars of *Chrysanthemum morifolium*.

b) Environnement et amelioration des plantes. Environment and Plant Breeding

W.D.HANSON. Genotypic differences for feedback inhibition of the photosynthetic processes in *Glycine max* (L.).

A.GHADERI and R.L.LOWER. Heterosis and phenotypic stability of F₁ hybrids in Cucumber under controlled environment.

L.L.PHILIPS and R.C.FITES. Seed production from a normally embryo lethal cross between *Gossypium hirsutum* and *Gossypium klotzchianum*.

F.H.HAYNES. Studies of heat tolerance in diploid species of tuber-bearing Solanum.

J.C.WYNNE. Use of accelerated generation increase programs in peanut breeding.

J.D.WYNNE, C.T.YOUNG and R.E.WORTHINGTON. Effect of temperature and origin of genotype on fatty acid and amino acid composition of peanut seeds.

c) Germination

J.F.THOMAS and C.D.RAPER Jr. Effects of cultural practices on germinability of flue-cured tobacco seed.

J.F.THOMAS and C.D.RAPER Jr. Morphological response of soybean as governed by photoperiod, temperature and age at treatment.

J.F.THOMAS and C.D.RAPER Jr. Photoperiod, thermoperiod and light intensity effects upon floral initiation and development in tobacco.

J.F.THOMAS and C.D.RAPER Jr. Effect of nitrogen fertilization and leaf harvest on weight and germinability on flue-cured tobacco seeds.

J.C.COLOSI and E.D.SENECA. The effect of thermoperiod and photoperiod during seed maturation on the subsequent rate of seed germination in *Uniola paniculata* and *Iva imbricata*.

d) Horticulture

E.K.HORST and R.L.LOWER. A Phytotron study of the effects on photoperiod and temperature on flowering and growth in *Cucumis sativus* L. and *Cucumis hardwickii* R.

V.P.BONAMINIO and R.A.LARSON. Influence of temperature and substrate on the development of Easter Lily (*Lilium longiflorum* Thumb cv. "ACE").

V.P.BONAMINIO, C.H.MILLER and D.C.SANDERS.Effect of seedling vernalization on field performance of Bell Pepper (Capsicum annuum L.var."Yolo Wonder").

V.P.BONAMINIO and J.LOVE.Effects of four day/night temperatures on floral initiation in Kalanchoe hybrids (Kalanchoe blossfeldiana v.Poellnitz).

C.H.MILLER, D.C.SANDERS and V.P.BONAMINIO.Effects of sequential vernalization and treatment with Etephon during the seedling stage on subsequent growth, flowering and fruit set of Capsicum annuum.

J.LOVE.Effects of day/night temperature on growth and flowering of Kalanchoe blossfeldiana.

F.H.DELSCHIG and R.A.LARSON.Use of pre-planting treatments in the forcing of Caladium bicolor.

T.JANNICK and P.NELSON.Nitrogen requirements of beans and Chrysanthemum growing at two controlled environmental conditions.

V.P.BONAMINIO and R.A.LARSON.Influence of substrate **and temperature on the effectiveness of** • -rest in retarding plant height.

T.WEISS.Pumpkin growth and the nature of flower expression as affected by photoperiod, temperature **and nitrogen content of soil**.

T.J.MONACO.Susceptibility of several varieties of potato to alachlor under environmental **conditions that induce maximum sensitivity**.

A.J.PERTUIT.Influence of temperatures during long night exposures on growth and flowering of • Mace, Thor and Telstar Kalanchoe.

e)Modelisation mathématique:Mathematical Modeling

M.WANN, C.D.RAPER Jr and M.L.LUCAS.A dynamic model for plant growth :a simulation of dry matter accumulation for tobacco.

C.D.RAPER Jr.Relationship between growth and nitrogen accumulation in plants.

F.R.COX.Effect of temperature and irradiance on the growth and development of peanuts (Arachis hypogea L.).

C.D.RAPER Jr.L.R.PARSONS, D.T.PATTERSON and P.J.KRAMER.Relationship between growth and **nitrogen accumulation for vegetative cotton and soybean plants**.

C.D.RAPER Jr., D.T.PATTERSON, L.R.PARSONS and P.J.KRAMER .Relative growth and nutrient accumulation rates for tobacco.

C.D.RAPER Jr.J.F.THOMAS and E.K.YORK.Temperatures in early post-transplant growth:an evaluation of accumulated heat units for predicting **development of tobacco**.

f)Pathologie végétale.Plant Pathology

P.BRANT and C.E.MAIN .Effect of temperature upon the development of a foliar disease of Tobacco.

R.E.WELTY. Anthracnose disease in alfalfa.

g) Physiologie et ecologie. Physiology and Ecology

D.A.BROWN. The effect of high temperature stress at specific stages of development on the growth and yield of soybeans.

I.A.MENDELSSOHN and E.D.SENEC. The effect of salinity ammonium concentration, and thermoperiod on the growth and nitrogen metabolism of the salt marsh grass Spartina alterniflora.

J.W.BURTON and C.A.BRIM. Nitrogen excretion from soybean nodules.

H.D.GROSS. Some observations on the effects of cool-day/warm night regimes on soybean growth.

L.L.MEDLEN. Effect of Common ragweed (Ambrosia artemisiifolia) aqueous leaf leachate on tobacco (Nicotiana tabacum) seedling growth.

R.P.PATTERSON. T. yater stress and nitrogen fixation.

J.F.THOMAS. Environmental physiology of Glycine max (L) Merrill.

J.W.VICKERS and D.A.EMERY. Response of spanish peanuts to pre-flowering and post-flowering alterations of photoperiod.

I.MENDELSSOHN and E.D.SENEC. Effect of soil aeration and thermoperiod on growth of Spartina alterniflora.

G.F.PEEDIN and C.D.RAPER. Growth, efficiency of nitrogen accumulation and net carbon exchange rates of flue-cured and burley tobacco.

G.S.HINER and T.RUFTY. Temperature effects on manganese uptake and toxicity in flue-cured tobacco.

G.H.ELKAN and J.C.WYNNE. Effect of host plant, Rhizobial strain and temperature on nitrogen fixation.

g) Culture de tissus. Tissue culture

R.H.SMELTZER, R.L.MOTT and A.MEHRA PALTA. In vitro clonal propagation from loblolly Pine embryos.

h) Zoologie. Zoology

Photoperiodic Time measurement in the Male Lizard Anolis carolinensis.

III.DUKE UNIVERSITY.PHYTOTRON.ANNUAL REPORT 1976

Editorial Note:Phytotron Director, H.HELLMERS, sent us the 1976 Annual Report of the Duke University Phytotron (USA) in June 1977. We were planning **to diffuse** a large part rapidly but unfortunately delays, beyond our control, made it impossible.In this issue, however, we take up the subject again, since we think that much of the information is still current.

Those desiring additional information should contact:

Dr.H.HELLMERS , Director of Phytotron
Department of Botany
Duke University
Durham NC 27706, USA

X

X

X

In his accompanying letter, the Director of the Phytotron gave us the following additional information certain to interest readers:

The Phytotron continues to be used for an increasing variety of experiments, all related to environmental effects on plants.Two factors contribute to this ever changing use of the facilities.One, the number of scientists that are becoming aware of the unique capabilities is increasing.Two, the Phytotron is the best place in the nation to conduct experiments on many of the current environmental problems which are associated with food and fiber production and drought and air pollution effects.

"The CO₂ control and monitoring system and a light sensing and recording system for the chambers and greenhouses are now operating. The automatic watering system also is installed and available for those experiments which would benefit from its use.

"In the fall of 1976 I had the good fortune of spending two months in Japan as a guest of Professor MATSUI and the Japan Society for the Promotion of Science.In addition to being at his laboratory, the Biotron at Kyushu University, I spent considerable time visiting Phytotrons and seeing the research being conducted in controlled environment facilities throughout the country.

"Phytotronic research has been a major endeavor in Japan for many years as they started building phytotrons shortly after Dr.WENT completed the first one at the California Institute of Technology in 1949.Innovations continue to be made in their existing and new phytotrons. I visited two new phytotrons: One was at the Forest Experiment Station which has seven meter tall temperature controlled glasshouses. The other was at the Research Institute for Environmental Studies. The latter has a bank of temperature controlled glasshouses attached to the south wall on each of the three floors of the building. This provides ready access to the chambers and laboratories inside the building.I also had the opportunity to discuss with the manufacturers some of the engineering aspects of new equipment which included chamber designs and monitoring and control systems. Root temperature control is built into some of their new chambers and glasshouses. One thing I observed was that both the new and old equipment worked well and that this was due to the fact that each laboratory had an efficient maintenance staff.

" The research being conducted was most informative.Many scientists are working on a problem that I have been interested in for a long time, which is the determination of the potential growth rate of plants.The approach to the problem in several laboratories is to monitor and control the conditions in a chamber by computers.The computers are fed data from sensing systems that measure one or more parameters of growth of the plants in the chamber and this information is used by the computer to control the conditions in the

chamber. The methods and techniques for several systems as well as results are published in "Environment Control in Biology" which is the Journal of the Japanese Society of Environment Control in Biology, University of Tokyo Press, Tokyo, Japan. The Journal is published in Japanese and English with a summary in both languages.

"In Japan, the flowers and the countryside were as beautiful as the pictures in the travel brochures so the trip was pleasurable as well as scientifically rewarding."

1976 ANNUAL REPORT OF PHYTOTRON. DUKE UNIVERSITY

Introduction.

The Duke University and the North Carolina State University Phytotrons form the Southeastern Plant Environment Laboratories, a regional facility available to all biologists who need controlled environment conditions to carry out their research programs. A unique feature is that the Phytotrons are service facilities and not institutes. There is no internal program or staff of scientists that dictates the scope of research. Consequently, the Phytotrons are available to all scientists regardless of their location or affiliation. Thirteen of the 30 scientists that used the Duke University Phytotron in 1976 were from universities and research organizations not affiliated with Duke University and from as far away as Florida and California.

Use by scientists from throughout the country is possible because the daily routine care of the plants is done by the Phytotron staff. In addition, the staff carries out a preventative maintenance schedule of all equipment which results in a high degree of reliability. Consequently, it is extremely unlikely that an experiment will be disrupted due to a mechanical or electrical failure.

Some researchers stay at the Phytotron during the entire experiment but many spend a minimum amount of time, usually at the beginning and termination of the experiment. Office and laboratory spaces are available to those that need them.

The Duke University unit was designed specifically to provide a wide range of conditions for plant growth. This is accomplished by having 40 chambers with artificial light systems and the capability of controlling temperature, humidity and CO₂ concentration and six temperature controlled glasshouses all on one floor. Plants are grown on trolleys that for many experiments are moved daily from one controlled environment to another to provide an even greater combination of conditions. For example, by using the greenhouses alone, thirty-six combinations of day and night temperature can be attained and if the chambers are used in conjunction with the greenhouses the possibilities are further increased. The almost unlimited possibilities for control and therefore variation of the environmental factors form a challenge to scientists to design experiments to take full advantage of the capabilities of the facility.

RESEARCH PROJECTS

Each year projects are brought to the Phytotron which are new in terms of ideas and challenging in terms of uses and modifications of the equipment to meet the needs. Twenty six projects in the areas of plant physiology, population genetics, ecology and plant growth and development occupied the facilities in 1976. The following brief summary of the projects indicates the broad scope of research conducted in the Phytotron. Some of the projects are continuing into 1977. Duke University is mentioned only in the studies that were conducted cooperatively. Where no specific organization is given the research was by the faculty and graduate students of Duke University.

The affect of environmental factors on photosynthesis and the development of the photogynthetic apparatus was investigated for several plant species. The various studies were conducted by scientists from the U.S. Department of Agriculture laboratories in Mississippi, the University of Chicago, the University of California in Los Angeles, DeKalb Seed Company and Duke University. How the environment affects crassulaceous acid metabolism in Sedum species from the Southern Rocky Mountains is the subject of a continuing study. Several years ago ultraviolet lamps were installed in air ducts of some of the chambers to produce ozone to study its effects on pine: Now another experiment is underway to study absorbance and reflectance of UV light by arctic and alpine plants. Scientists from Utah State University and Duke University are cooperating on this project.

In cooperation with a U.S.D.A. scientist from Colorado an experiment is being conducted on pressure induced water and solute flow in decapitated soybean roots. Another study uses soybean and cotton plants to investigate humidity as a control of leaf water potential and its affect on growth.

Scientists from the University of Florida grew peanut plants under a range of temperatures to learn more about the growth characteristics, the growth potential and the net yields. Under the best environment, plants produced over 500 pegs. Other scientists from the University of Florida are studying the translocation of chemicals through the epidermis of orange fruits during various stages of development as affected by a cross-gradient of temperature and humidity.

There were several ecological studies started. Plants of several species are being grown under ranges of conditions for comparison with field observations of plant distribution along environmental gradients. Also, the role of calcium in the growth of Saguaro cactus plants is being investigated. The U.S. Forest Service sponsored a study of the germination requirements of woody plants from the Alaskan tundra and taiga. Experiments were completed on flooding and salinity effects on beach grass.

Work was started by Weyerhaeuser Company scientists from Arkansas to shorten the two year period normally required to ripen loblolly seed. A crop of mycorrhizae was grown on the roots of Sorghum vulgare to be used in a tree nursery inoculation study by the International Paper Company.

How individuals and local plant populations adapt to temporal fluctuations in the environment that occur in the life cycle of the individual plants was investigated by a University of Chicago scientist.

One population study was a comparison of the growth of Saxifrage cespitosa collected from a span of 137 degrees latitude. Another was an investigation of differences of three local but contrasting populations of Plantago lanceolate.

a) Publications in 1976

Photosynthesis was the primary subject of three of the papers. ALBERT B et al. (1) compared the chloroplast's lamellar system and the photosynthetic activity of virescent and wild type peanut leaves. The results indicated that chlorophyll deficient leaves had fewer, but larger photosynthetic units than the normal green leaves. BOURQUE et al. (3) used Jackbean, Canavalia ensiformis L. and looked at the effects of inhibitors of protein and RNA synthesis and their relationship to greening. Net photosynthesis as affected by temperature, light and the rate of photorespiration and the C4 pathway of CO₂ fixation in smooth pigweed Amaranthus hybridus L. was studied by PATTERSON (10). Photosynthetic acclimation of Pinus taeda L. to temperature was investigated by STRAIN et al. (12). Changes in the photosynthesis process in crassulacean acid metabolism (CAM) plants as affected by light intensity, photoperiod and temperature was reported by CREWS et al. (4).

Water relations of plants have been and continue to be investigated. This past year results of a study on changes in water potential and stomatal resistance following stress applied at different stages of plant growth were reported by SIONIT and KRAMER (11). They worked with soybean, (Glycine max L.Merr.) and sunflower (Helianthus annuus L.).

Root growth of plants grown over permafrost is reported in a paper by BILLINGS et al. (2). This study demonstrated a unique use of the Phytotron. A box was developed in which a permafrost was formed and the depth of permafrost could be raised or lowered by changing the temperature of the glycol system in which the actual soil units were placed. In addition, by placing the box in a temperature controlled growth chamber the temperature and growth of the plants could be regulated. Between the two sets of controls soil temperature gradients could be established that were in agreement with those observed in the field.

Plant growth analysis through the use of a range of conditions have been the subject of many papers. The most recent one by GOOD and GOOD (6) reports on the results of top and root growth of Pinus taeda L. seedlings under three temperatures.

TEERI (13) working with high arctic plants, Saxifraga rivularis, showed that nearly continuous light of 0.3 ly/min for 7-9 days is required for floral development from per-formed buds. Flower bud initiation and formation occurred under a non-flowering light regime of several hours of darkness per day. The same effect occurred if the light irradiance was lowered to 0.1 ly/min for several hours each day.

Population genetics was represented by only one publication this year. WYATT working (14) with a collection of Asclepias tuberosa L. from throughout its range studied local population differences. Due to the insect free conditions in the Phytotron he was also able to produce flowers at required times to study the effects of cross pollination on fruit, WYATT'S publication also included the results of his work on a predictive model for fruit to flower ratios for Asclepias in 1976.

Chemotaxonomy, which could be considered as population genetics, was studied in fourteen inbred stocks of four species of cotton, Gossypium, (PARKS et al. (9)). The flavonoid constituents of the flower petals were more stable than those of the leaves.

Biochemical studies on the synthesis of compounds requires a reliable supply of uniform plant material grown preferably under known conditions. Two papers by JEFFS et al. (7-8), on alkaloid synthesis in plants grown in the Phytotron were published in 1976. The facilities have been used frequently to obtain uniform and known-condition-grown material.

Technical papers and books have been published that describe the Phytotrons, their operation, use and potential use. The most recent is a Technical Report for the World Meteorological Organization by DOWNS and HELLMERS (5).

From these publications it is quite evident that a wide range of plant species have been grown in the Phytotron. These have included tropical to arctic species and coastal to alpine species. No one has been restricted in his research because it was not possible to grow the plants. The biggest challenge to date probably has been lichens. Several species were grown successfully under a range of conditions.

Seven theses for Doctor of Philosophy or Master of Science degrees were also completed in 1976:

1. BATES, MAYNARD E. Growth responses of containerized southern pine seedlings to temperature and light in controlled environment greenhouses (Ph.D.).

- 2.KARLE J.M.Structural and biosynthetic studies of the mesembrine alkaloids (Ph.D).
- 3.LONGSTRETH, DAVID J.The effect of salinity and tidal inundation on photosynthesis and plant water relations of Spartina alterniflora Liosel (Ph.D).
- 4.MONTES, Rubn.Seasonal variations in nitrification in soil from three vegetation types.(M.A.).
- 5.PRIMACK, Richard.The evolutionary basis of population dynamics in the genus Plantago (Ph.D).
- 6.SHAVER Gaius.Ecology of roots and rhizomes in graminoid plants of the Alaskan coastal tundra (Ph.D).
- 7.SILANDER John.The genetic basis of the ecological amplitude of Spartina alterniflora on the outer banks of North Carolina (Ph.D).

PUBLICATIONS in 1976

- 1.ALBERTE R.S., HESKETH J.D. and KIRBY J.S.Comparisons of Photosynthetic activity and lamellar characteristics of virescent and normal green peanut leaves.Z.Pflanzenphysiol. Bd 77 5.152-159.1976.
- 2.BILLINGS W.D., G.R.SHAVER and A.W.TRENT.Measurement of root growth in simulated and natural temperature gradients over permafrost.Arctic and Alpine Research vol.8, n°3 1976 pp.247-250.
- 3.BOURQUE D.P., P.N.Mc MILLAN, W.J.CLINGEN PEEL and A.W.NAYLOR.Comparative effects of several inhibitors of chloroplast thylakoid membrane synthesis in greening jack bean.Bot.Gaz.137 (3): 279-284.1976.
- 4.CREWS C.E., S.L.WILLIAMS, H.M.VINES and C.C.BLACK.Changes in the metabolism and physiology of Crassuleacean acid metabolism plants grown in Controlled environments.In CO₂ Metabolism and Plant Productivity.R.H.BURRIS and C.C.BLACK (Eds).Univ.Park Press, Baltimore Maryland 1976.
- 5.DOWNS R.J. and H.HELLMERS.Controlled climate and plant research.World Meteorological Organization, Technical Note n°148 Geneva Switzerland 1976.
- 6.GOOD R.E. and N.F.COOD.Growth analysis of pitch pine seedlings under three temperature regimes.For.Sci.vol.22 pp.445-448-1976.
- 7.JEFFS P.W., D.B.JOHNSON, N.H.MARTIN and B.S.RAUCKMAN.Post tyrosine intermediates in the biosynthesis of mesembrine alkaloids and stereochemistry of protonation at C-7 in the formation of the octahydroindole skeleton.Journ.of Chem.Soc.Chemical communications London 1976.
8. JEFFS P.W.and J.D.SHARVER.Biosynthesis of ophiocarpine.Induction of a stereospecific label through transannular cyclization .Journ.of Am.Chem.Soc.98, 4301-4310.1976.
- 9.PARKS C.R., S.S.SANDHU and K.R.MONTGOMERY.Floral pigmentation studies in the genus Gossypium.IV.Effects of different growing environments on flavonoid pigmentation. Amer.J.Bot.59 (3) 158-164.1972.
- 10.PATTERSON D.T.C₄ photosynthesis in smooth pigweed.Weed Sci.Vol.24 n°1, January 1976 pp.127-130.

- 11.SIONIT N.and P.J.KRAMER.Water potential and stomatal resistance of sunflower and soybean subjected to water stress during various growth stages.Plant Physiol.1976 58, 537-540.
- 12.STRAIN B.R., K.O.HIGGINBOTHAM and J.C.MULROY.Temperature preconditioning and photosynthetic capacity of Pinus taeda L. Photosynthetica 10(1) 47-52, 1976.
- 13.TEERI J.A.Phytotron analysis of a photoperiodic response in a high arctic plant species.Ecology vol.57, n°2, Early Spring 1976 pp.374-379.
- 14.WYATT R.Pollination and fruit set in Asclepias: a reappraisal.Amer.J.Bot.63 (6) 845-851, 1976.

x x

x

IV.K.A.TIMIRIAZEV INSTITUTE OF PLANT PHYSIOLOGY (Moscow USSR) I

Prof.B.P.STROGONOV and Dr.V.I. KEFELI

I.The history of the Institute of Plant Physiology

The Institute of Plant Physiology of the USSR Academy of Sciences is the oldest scientific institution in the Soviet Union dedicated to studies in plant physiology. It evolved from the scientific cabinet and associated laboratory of plant physiology and anatomy of the Imperial Academy of Sciences which were organized in 1890. The founder of the cabinet and its first director was Academician A.S.Famintsyn.

After Famintsyn's death in 1918 the laboratory was headed by such distinguished scientists as Academicians V.I.PALLADIN (1919-1922), S.P.KOSTYCHEV (1922-1931) and A.A.RIKHTER (1931-1934).After the laboratory was reorganized into the Institute of Plant Physiology in 1934, RIKHTER became its first director.In 1938 he was succeeded by Academicians A.N.BAKH (1938-1946) and N.A.MAKSIMOV (1946-1952).From 1952 up to the present the Institute of Plant Physiology is headed by Academician A.L.KURSANOV.

Under leadership of Academician A.L.KURSANOV the equipment of the Institute has been modernized and much more attention to problems of biochemistry, biophysics and molecular biology is paid by workers of the Institute.KURSANOV'S own scientific interests mainly lie in the domain of assimilate transport in plants but he also is studying the products of secondary metabolism. His work has helped to strengthen the ties between plant physiology and biochemistry. His knowledge of biochemistry and ability to apply its principles and methods for elucidating the essence of physiological processes are characteristic of his leadership and have contributed much in raising plant physiology to its present-day level.

On KURSANOV'S initiative the journal "Fiziologia rastenii" (Plant Physiology) was founded in 1954. The journal has helped to unite the plant physiologists of our country.In 1958 an English translation of the journal began to appear in the USA. KURSANOV has devoted much energy to facilitate the rebuilding of the institute and its Phytotron.

The main aim of the Institute, as the central institution for plant physiology in the country, is the study of basic phenomena and elucidation of the internal organization of life processes and the determination of means of controlling the processes. The work of the Institute is accordingly directed at the solution of the following problems; photosynthesis as the basis for high plant productivity; translocation and storage of substances; root metabolism as the basis of mineral nutrition of plants; regulation of the life activity of plants by means of physiologically active substances; resistance of plants to unfavorable environmental conditions and means of enhancing the resistance.

The ultimate aim of these investigations is to find ways of raising crop yields, the main task of the plant physiologist being the elucidation of the internal organization of life processes, their self-regulation and coordination depending on the conditions of existence of the plants. Research along novel lines is also being carried out in the Institute.

Scientific relations with other biological institutions in our country and with scientists of foreign countries consist in carrying out joint investigations, rendering of consultative aid, active participation in the practical application of the results of completed studies, organization of expeditions, exchange of information on new methods, organization of joint meetings and conferences. Plant physiology investigations in the Soviet Union are coordinated by special scientific councils such as that for photosynthesis, that for plant physiology and biochemistry, for the scientific basis of chemization of agriculture, and for trace elements in plant growing and animal breeding.

At present there are 15 laboratories and 9 groups in the Institute. Some of the more sophisticated apparatus is located in special "cabinets". Finally there is the phytotron, a unique installation which permits the study of the life activity of plants under strictly controlled conditions. There is a well equipped photographic laboratory.

II. Laboratories of the institute

- 1) A.A. RIKHTER LABORATORY OF PHOTOSYNTHESIS
(Head, A.A. Nichiporovich, Corresponding
Member of USSR Academy of Sciences)

The Laboratory of Photosynthesis was organized in 1933. In the initial period most of the work was of a methodological nature. Simultaneously the rate of photosynthesis of citrus and wheat plants under various conditions of water supply was measured as a characteristic of the physiological state of the plants. Extensive studies were made of photosynthesis during the ontogenesis of plants and of the dependence of the process and possibilities of its regulation by varying the concentration of carbon dioxide (CO₂ nutrition) and the importance of such nutrition for crop yields. Illumination conditions and photosynthesis of woody plants as factors affecting the productivity were also studied.

A balance equation for crop yield was proposed which involved the area of the assimilation apparatus, intensity and duration of photosynthesis, rate of respiration and loss of organic substances due to the death of organs.

Subsequently the main line of investigation in the laboratory was the development of the theoretical basis of the problem of photosynthesis as a factor of plant productivity.

The aim of further work in the laboratory is to study the principles of raising the photosynthetic productivity of plants. This includes a study of the potential activity of the photosynthetic apparatus in various types of plants and of the factors which control it; an investigation of the regulatory systems responsible for adaptation of plants to changing environmental conditions and primarily to such factors as light, CO₂ and O₂ concentration, nitrogen nutrition; a study of the interrelationship between

photosynthesis and the utilization of assimilates in growth and organogenesis of the plant as a whole; a study of the laws regulating the interaction between plants in model plant communities under controlled conditions in closed systems with account of the balance of energy and matter; working out of the principles for cultivation of plants under maximally controlled conditions.

There are 33 workers in the laboratory at present.

2) Laboratory of the molecular basis of intracellular regulation

(Head, V.E. Semenenko, Candidate of Biological Sciences)

The Laboratory of the Molecular Basis of Intracellular Regulation was organized in 1966. There are 15 workers in it at present.

The laboratory developed from the Group of Regulated Photobiosynthesis which carried out an extensive study of the physiology and biochemistry of unicellular algae and developed the theoretical foundations of high-intensity photosynthetic systems of the industrial type encountered in cosmic biology investigations and in work involving the utilization on photosynthesis for practical purposes. Various forms, strains and mutants of unicellular photoautotrophic algae have been investigated. Their physiology and biochemistry under cultivation conditions have been investigated in detail and methods for intensifying their productivity and regulating the biosynthetic pathways in the photosynthesizing cells have been developed.

3) Laboratory of translocation of substances

(Head, Academician A.L. Kursanov)

The Laboratory of Translocation of Substances was organized in 1954. At present there are 26 workers in the laboratory.

The concept of the active metabolic nature of assimilate transport processes in the parenchyma tissues and phloem is being developed in the laboratory. This idea arose at an early period of work in the laboratory when a close relation was observed to exist between the rate of respiration and the rate of absorption of organic substances by plant tissues immersed in a solution. In the same series of investigations it was shown that the accumulation of nitrogenous substances in rye seeds is independent of the transpiration rate of the spike. The possibility of movement of nitrogen-containing substances in the direction of increasing adsorption gradient of the stem was also demonstrated.

The metabolic concept of phloem transport was developed in latter work carried out with isolated conducting bundles from sugar beet plants. A high rate of respiration of conductive tissues was discovered which exceeded by several times the rate in cells of the major part of the petiole parenchyma. The intense respiration of the conducting bundles is a result of enhanced activity of certain enzymes of carbohydrate-phosphorus metabolism, and of a higher content of acid-soluble nucleotides and nucleoside diphosphate sugars.

4) Laboratory of storage substances

(Head, Professor A.A. Prokofiev)

The Laboratory of Storage Substances was organized in 1953; 23 workers at present. At that time knowledge about accumulation of substances in storage organs, and particularly in dry fruits, was meager. Little was also known about the physiology of the storage organs and the relation between the processes taking place in them and accumulation of storage substances.

Initially, the localization and dynamics of accumulation of storage substances in the tissues of fruits and seeds and clarification of the relationship between feeding and storing organs (primarily in oil plants) were the main points of interest of the laboratory. Subsequently, other plants were studied which accumulated various storage substances in both seeds and vegetative organs.

At present the main task of the laboratory is a study of the physiology of storage organs and elucidation of the nature of the relation between the metabolism of these organs and the accumulation of storage substances. Special attention is paid to the determination of the factors on which the level of storage product accumulation in reproductive and vegetative storage organs depends. The mechanism of storage of substances in various tissues is also being studied. The ultimate aim of this work is to find means of raising the level of accumulation of economically valuable substances stored by plants.

5) Laboratory of root nutrition (Head,
D.B.Vakhmistrov, Doctor of Biological Sciences)

A laboratory to study the root nutrition of plants was created in 1933 in the Institute. There are now 18 workers in the laboratory.

In the early 1940's the main subject of study was absorption of salts by the root. These investigations established the role of exchange adsorption of both-cations and anions from the solution and the role of contact exchange in absorption of the ions from the soil. It was also shown that, depending on the salt content in the medium and in the plant, the role of transpiration could be either negligible or decisive.

In the 1950 and 1960's the participation of mineral nutrients in metabolism was the central problem of the laboratory. It was found that phosphorus deficiency when occurring singly evoked much greater damage in root and leaf metabolism than did simultaneous phosphorus and nitrogen deficiency. Plants subjected to phosphorus deficiency and then placed in a complete nutrient medium exhibited signs of poisoning and death of leaves. It was suggested that this could have been due to synthesis in the root and transfer to aerial parts of the plant of some products of anomalous phosphorus metabolism. Phosphorus deficiency was found to make root respiration resistant to cyanide; in contrast, the sensitivity of leaf respiration to the poison was enhanced. Uptake of exogenous amino acids by roots was studied in sterile cultures; depending on the taxonomic position of the plant the acids could become involved in root metabolism either by deamination or transamination.

6) Laboratory of biochemistry of trace elements
(Head, Academician Ya.V.Peive)

The Laboratory of Biochemistry of Trace Elements was organized in 1963. The laboratory consists of 23 workers.

Most work in the laboratory is centered on a study of metal containing enzymes and enzyme systems involved in nitrogen metabolism of plants and particularly in the fixation of molecular nitrogen, reduction of nitrates and functioning of leghaemoglobin in leguminous plants. An important part of work in the laboratory is the study of the role of trace elements in primary uptake of nitrate nitrogen and in the formation of free amino acids; the role of copper in leguminous plants; trace elements and enzyme systems in the root nodules of leguminous plants; the specific role of the leghaemoglobin present in the nodules and its relation to other iron proteins of the nodules.

7) Laboratory of water conditions

(Head, Professor V.N.Zholkevich)

The laboratory of Water Conditions was organized in 1948. There are now 29 workers in it.

Early work on water conditions in plants was of a comparatively applied nature and was carried out in field conditions. On basis of these physiological investigations rational watering regimes were worked out which took into account the concrete soil and climatic conditions. It was found that the most profitable means of watering was with sprinklers. Combined with mineral fertilizers appreciable increases of crop yield and an improvement of quality (protein content) of wheat grain could be attained.

At a later stage of the work the applied character of the investigations was retained but a greater theoretical trend appeared. A detailed study of the physiology of irrigated plants was carried out. An objective, sensitive physiological method (based on the suction force and concentration of cell sap) was developed which could be used for determining timing and optimal conditions of watering. A check under production conditions showed that the method was highly efficient.

8) Laboratory of growth and development of plants

(Head, Academician M.Kh.Chailakhian)

This laboratory was organized in 1935 and consist now of 29 workers. Initially two large problems attracted the attention of the laboratory; the physiology of generative development and the physiology of growth and regeneration. Later on, the problem of pollination and fertilization of plants was added.

The physiology of generative development of plants has been the main line of scientific research work in the laboratory since its organization. It includes a study of the main laws of ontogenesis in connection with the effect of environmental conditions and the interaction of organs; hormonal regulation of transition processes of higher plants from vegetative growth to generative development; molecular-genetic basis of development and metabolism in the ontogenesis of plants.

9) Laboratory of nucleic acids and protein biosynthesis in plants

(Head, O.N.Kulayeva, Doctor of Biological Sciences)

The Laboratory of Nucleic Acids and Protein Biosynthesis was organized in 1971 . There are 11 workers in the laboratory. This was preceded by a period of theoretical and experimental training of the future members of the laboratory and the formation of its main lines of research which took place within the Laboratory of Translocation of Substances.

During this time a range of problems evolved which focused on the task of elucidating the internal mechanisms of regulation of nucleic acid and protein synthesis in plant cells which define their functional activity. Accordingly, the following problems are being studied: molecular mechanisms of the regulatory effect of phytohormones on nucleic acid and protein synthesis; mechanisms of nucleic acid and protein synthesis at early embryogeny of plants. Of special interest is the process of intracellular differentiation, the peculiarities of RNA and protein synthesis during senescence of plant cells and finally a search of means of delaying senescence and overcoming the changes in metabolism and structural organization of cells which are elicited by this process.

10) Laboratory of chemical regulation (Head, Yu.V.Rakitin,
Corresponding Member, USSR Academy of Sciences)

The laboratory was organized in 1944 and now consists of 16 workers.

The main direction of work of the laboratory is a study of the mechanisms of the stimulating, inhibitory and lethal (herbicide) effects of chemical compounds and the elucidation of the principles and means of applying these compounds for regulation of vital processes in plants.

Underlying the work of the laboratory is the concept proposed by Yu.V.Rakitin, of the physiological nature of the stimulating, inhibiting and lethal effects of chemical and physical agents. It is assumed that all physiologically active agents can be divided into two groups, those which are required for normal vital activity of plants (e.g. many mineral substances, oxygen, carbon dioxide, sugars, amino acids, phytohormones) and those that are foreign to the plants (e.g. 2, 4-D, ionizing radiations, temporary anaerobiosis). In a certain range of concentrations and doses, the factors of the first group are involved in metabolism of plants as indispensable components. Deficiency of these factors results in violation of metabolism, and on readjustment of the factors metabolism returns to the normal state.

It) Laboratory of tissue culture and morphogenesis (Head,
R.G. Butenko, Corresponding Member, USSR Academy of Science)

In 1963 an inter-laboratory group for isolated tissue and organ culture was created which consisted of A.M. SMIRNOV from the Root Nutrition Laboratory, R.G. BUTENKO from the Laboratory of Growth and Development and M.S. BARDINSKAYA from the Laboratory of Translocation of Substances.

Work in the Institute on development of the technique of culture of isolated cells, tissues and organs was facilitated by the existence of conditioned rooms and the phytotron and also of specialized rooms for work under sterile conditions. In 1970, the Laboratory of Tissue Culture and Morphogenesis, with R.G. BUTENKO as its head, and a group of isolated organ culture under A.M. SMIRNOV, were organized. There are now 14 workers in the laboratory.

Work in the laboratory is now being carried out along the following directions, 1) Physiologico-biochemical and genetic mechanism of cytodifferentiation and morphogenesis in vitro. 2) Production and investigation of highly productive mutants of strains of cells synthesizing steroid saponins and panaxosides. 3) Utilization of cells grown in vitro as models for studies of storage processes, hardiness, reproduction and growth of cells.

12) Laboratory of cold resistance
(Head, I.I. Tumanov, Corresponding Member, USSR Academy of Sciences)

The laboratory was founded in 1940. It now consists of 24 workers.

In connection with the desirability of cultivating subtropical plants in relatively cold regions of the country a study was carried out on wintering of citrus and tea plants. Field studies resulted in practical proposals for the protection of citrus plants from freezing. Much attention was paid to a study of the dynamics of frost resistance of northern woody plants which wintered under natural conditions in the Moscow Region. Conditions required for the development of maximal frost resistance were determined. As a result plants were obtained in the phytotron which were not destroyed by frost. Birch and pine trees and black currant shrubs could endure freezing down to -235°. After a study of the conditions of vitrification of water in plant cells it was possible to obtain frost resistant plants also by other means. Winter wheat which was first hardened in the laboratory and then subjected to rapid deep cooling and a safe way of thawing could endure temperatures down to -195°. It was found that hardened plants, which could endure even ultra-low temperatures, perished upon very rapid thawing. The physiological mechanism which makes plants resistant to frost is studied. It consists of the plant entering a state of deep dormancy and passing through the first and second hardening phases.

13) Laboratory of drought resistance (lead, P.A.Renckel, Corresponding Member,
Academy of Pedagogical Sciences of USSR)

The Laboratory of Drought Resistance was organized in 1939 and now consists of 19 workers. The main interest of the laboratory lies in the investigation of such properties of the cytoplasm as relative viscosity, elasticity and hydrophilicity of colloids. Elasticity of the cytoplasm is shown to be related to the ability of plants to endure dehydration; viscosity is related to their ability to endure relatively high temperatures, i.e. to acquire heat resistance.

Cactuses and other succulent plants are found to possess high cytoplasm viscosity and very low elasticity; this is ascribed to their high heat resistance and inability to endure dehydration. Other groups of xerophytes survive prolonged and profound dehydration and high temperatures and their cytoplasm is viscous and elastic (euxerophytes). On the other hand the hemixerophytes, which use groundwater, were found to be incapable of enduring prolonged and severe water deficiency and the viscosity and elasticity of their cytoplasm were relatively low.

The relative viscosity and elasticity vary strongly during ontogenesis of the plants and drop at the critical time; this, naturally, increases the sensitivity of the plants to drought. The cytoplasm viscosity and hence heat resistance of different parts of the plant are not the same. In cereals viscosity is the lowest in the leaves and highest in the generative organs, particularly in the glumes.

14) Laboratory of salt metabolism and salt resistance
(Head, Professor B.P.Strogonov)

In 1970 the Salt Resistance Group of the Laboratory of Heat and Salt. Resistance was reorganized as a separate laboratory. There are 15 workers now in the laboratory.

Previous investigations had shown that the characteristics physiological and anatomico-structural alterations in plants are more closely related to the relative concentrations of salts, i.e. to the salt composition of the soil, than to their total concentration. Under chloride salinization the halosucculent properties of the plants become particularly pronounced, whereas during sulphate or carbonate salinization alterations occur in the direction of haloxerocity.

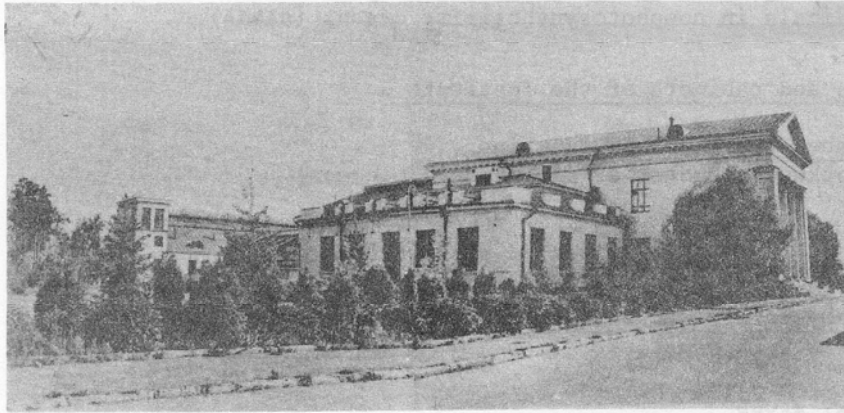
It could be concluded from the experiments that the toxic effect of salts on plants proceeds via metabolism and that as a result of changes in the latter intermediate, toxic products accumulate which are not present in the normally functioning organism. The formation and accumulation of such products are due to changes in enzyme reactions. It was found, in particular, that transformation of arginine under salinization conditions can be restricted to the formation and accumulation of putrescine as a result of suppression of the diamine oxidase activity by the salts. Thus the primary effect of salts is stimulation or inhibition of enzymic reactions responsible for the formation of toxic substances.

15) Laboratory of evolutionary and ecological physiology
(Head, Professor A.A.Shakhov)

The laboratory was organized in 1953. It now consists of 16 workers.

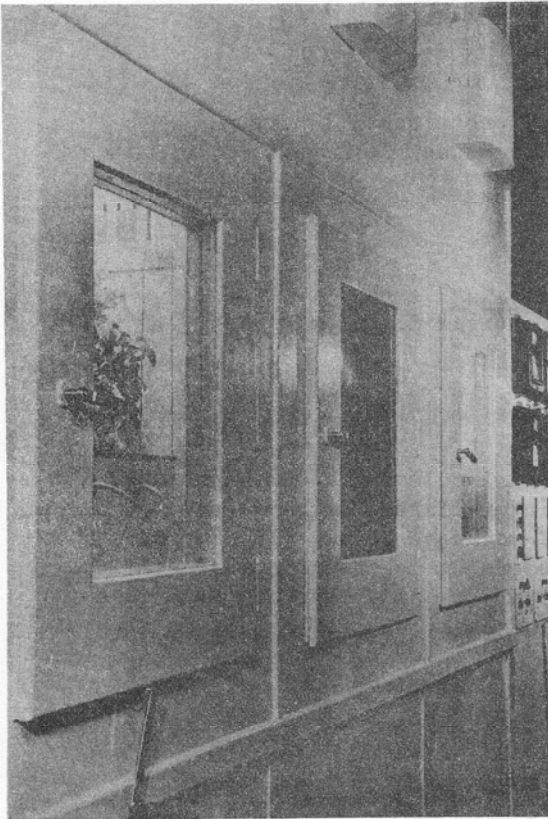
Two problems are being investigated in the laboratory. These are nonphotosynthetic transformation of light energy by plants and the effect of pulsed concentrated solar light on plants and the photoenergetic foundations of the evolutionary process in plants.

A study of the spectral properties of plants carried out in the laboratory showed that plants absorb considerably more radiant energy than is utilized in photosynthesis and is taken into account on determination of photosynthetically active radiation. From this fact and also on basis of the strong effect of concentrated light on nonphotosynthesizing organs it was concluded that nonphotosynthetic utilization and accumulation of light energy by plants occurs. The degree of nonphotosynthetic



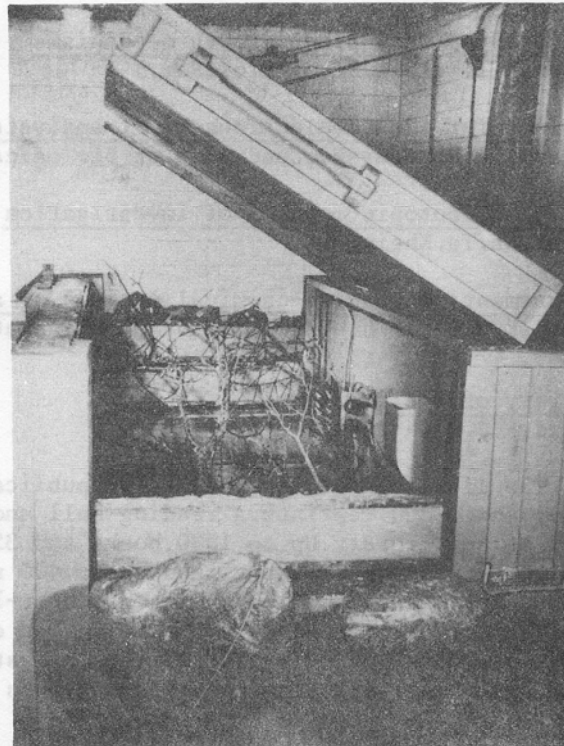
Institut K.A.TIMIRIAZEV de Physiologie Végétale.

K.A.TIMIRIAZEV Institute of Plant Physiology.



Enceinte climatisée du Phytotron.

Reach-in growth chambers of the Phytotron.



Enceinte de refroidissement et endurcissement au froid des plantes: dans une chambre à -10°C l'enceinte peut atteindre -60°C .

Frost room for plants: into -10°C room reach-in frost cabinets at -60°C .

transformation of vitally effective light energy in seeds, pollen grains and etiolated seedlings has been determined. One of the modes of nonphotosynthetic transformation and accumulation of light energy is the intensive photoinduced accumulation and conservation of free radicals in nonphotosynthesizing organs (seeds).

III. List of groups and cabinets of the Institute

- 1) Group of membrane structure and function (Head, Yu.G.Molotkovsky, Doctor of Biological Sciences)
- 2) Lipid group (Head, A.G.Vereshchagin, Candidate of Biological Sciences)
- 3) Group of the physiology and biochemistry of secondary metabolism (Head, Professor M.W.Zapromttov)
- 4) Seed physiology group (Head, Professor K.E.Ovcharov)
- 5) Group of the physiology of isolated organs (Head, Professor A.M.Smirnov)
- 6) Group of automatic regulation of physiological processes (Head, Professor A.F.Kleshnin)
- 7) Group of primary plant growth mechanisms (Head, V.I.Kefeli, Dr.of Biol.Sci.)
- 8) Cabinet for immuno-electrochemical analysis of proteins (Head, A.D.Volodarsky, Candidate of Biological sciences)
- 9) Group of isotopic methods of investigation (Head, Kh.Ya.Khein)
- 10) Department of physico-chemical methods of analysis (Head, E.M.Sorokin, Candidate of Physico Mathematical Sciences)

IV. Library of the institute (Head, R.S.Mosharova)

The library contains over 82700 publications, including 14000 books, 35000 magazines and 32300 reprints. A reading hall and inter-library exchange service are attached to the library. Up to 1000 books and 3500 magazine issues (118 Soviet and 86 foreign titles). The library is used by 400 readers. On the average 6870 publications are issued per month, 100 of them via the inter-library exchange service. From 25 to 30 publications are issued to other libraries each month. The library has an alphabetical index of books, journals and reprints, a systematic index of books, and a card index on plant physiology and biochemistry and papers published since 1961.

V. Artificial climate station (Phytotron) (lead, Chief Engineer N.A.Isakov)

The Artificial Climate Station has a complex of chambers and growth cabinets with controllable temperature, humidity and illumination which can be used to carry out a variety of investigations under prescribed environment conditions. The entire complex consists of the following growth, thermoregulated chambers and refrigerator boxes. The growth chambers in turn can be divided into chambers with natural and artificial illumination, and depending on temperature range; into warm chambers with temperature ranging between 20 and 35° and cold chambers with temperatures between 0 and 20° (Table).

At present there are 20 warm and 9 cold growth chambers with artificial illumination, 8 growth chambers with natural light , 11 thermoregulated chambers and 6 refrigerated cabinets.

Chambers and growth cabinets of the Artificial Climate Station					
Type of chamber	°C Temperature	Humidity x	Illumination type of lamp	Number of chambers	Area of chambers, m2
Warm growth chambers with artificial illu- mination	from 20 to 35	50-90	xenon	2	12
			reflecting	3	18
			fluorescent	15	120
Cold growth chambers with artificial illumination	0-20	60-90	fluorescent	3	15
	10-20	60-90		4	25
	0-20	60-90	mercury arc	2	10
Growth chambers with natural illumination	5-25	60-90	natural light	8	300
	(winter) 20-40		+xenon lamps		
	(summer)				
Thermoregulated chambers	20-35	60-90		3	50
	0-10	60-90		5	100
	10-0			3	35
Total				48	635
Cold chambers	100- - 70			5	5 m3
	-80- - 25	10-100		1	0.25 m3
Total				6	5.25

The artificial light chambers are supplied with variable height shelves whose distance from the lamps can be varied between 0.2 and 1.4 m. There are either 2 or 4 shelves in each chamber. The chambers are supplied with water, compressed air and electricity.

The natural light chambers are sections of the greenhouse. By means of automatic heating and cooling installations the temperature can be maintained between 0 and 25 in the winter and between 20 and 35 in the summer. The chambers are supplied with sources of additional light which are used during short winter days or in cloudy weather. The sources are 6 kW xenon lamps and 400 W mercury arc lamps.

The thermoregulated chambers are employed for storage of experimental material and for carrying out analytic work at constant temperature. Two thermoregulated refrigerated chambers with a temperature of 2° are employed for preparative biochemical work and are accordingly equipped. Benches have been installed which are- connecting electric apparatus.

In three chambers with shelves and benches the temperature can be maintained between 0 and 10°. In the three other chambers the temperature is kept below zero. In one of them the entrance consists of a chamber at -10° and this permits the temperature in the main chamber to be maintained at a lower temperature (down to -20°C).

Three thermoregulated chambers are designed for work in relatively warm conditions (from 20 to 31°C). One of them is specially equipped for work in darkness. It is located next to a growth chamber with fluorescent lamps and shares a common conditioner and a small lobby. The interior is painted black.

The two other thermoregulated chambers are employed for storage and cultivation of isolated plant tissues and organs.

The refrigerated cabinets are designed for experimental work at low temperatures. Six of the cabinets can be cooled to -70° . In one the temperature can be varied between

-25 and $+80$ C and the relative humidity between 10 and 100%.

The air temperature and humidity in each chamber or cabinet are maintained by means of separate conditioners and refrigerating installations which are located near the respective chamber.

Two types of conditioners are employed. In the warm chambers (20 -35°) the conditioners are of the KH-3 and KH-4 type. The conditioners in the cold chambers (0 -20°) were designed in the Institute shops. In the low temperature chambers and cabinets only the temperature is regulated.

Freons (Freon-12, Freon-13 and Freon-22) are used as refrigerants since they do not exert an injurious effect on living organisms, are not inflammable and are explosion-proof. Water from an artesian well at 8° is also used for cooling.

Various types of lamps are used in the growth chambers with artificial light: 500 W reflecting incandescent lamps, 400 W mercury-arc, 6 and 20 kW xenon lamps and fluorescent lamps of various types in the 65 to 150 W range.

The 20 kW xenon lamps are air-cooled. They are arranged above a glass ceiling along which water flows. The ceiling is essentially a glass filter which absorbs short wave (<1 300 nm) lethal ultraviolet rays and also much of the infrared rays. The 6 kW xenon lamps are enclosed in a glass cylinder in which cool water is circulated.

The spectral distribution of radiation from the xenon lamps is similar to that of solar radiation and intensities (500.000 erg/cm²/sec) close to the maximal solar light intensities can be attained.

The 300 and 500 W reflecting incandescent lamps provide a high irradiance, are easy to work with and the light from them possesses a suitable spectral composition.

The irradiance of the mercury-arc lamps (400 W) is sufficiently high and the lifetime of the lamps is long but there is a predominance of radiation in the blue-green part of the spectrum,

The 65, 80 and 150 W fluorescent lamps employed at the Station possess a suitable spectral characteristic and an irradiance which is sufficient for shade plants. With these lamps it is possible to obtain a uniform irradiance over a large area.

Normal 24 hours operation of the chamber and plant cabinet complex is ensured by a system of automatic regulation and controls. Automatic regulation systems for temperature, humidity and illumination are employed and also remote control and recording systems. The temperature, humidity and illumination automatic control systems include regulating apparatus, accessory instruments and actuating mechanisms which are an inherent part of the systems.

Remote control, signalization of parameter deviations, and switching are carried out at a central control board.

The complex equipment and machinery of the Station is serviced by specialists working in the Institute. Some of the equipment required for the Station is made in the workshops of the Institute.

The Institute consists of three buildings with a total area of 10.000 sq.m. The greenhouses of the phytotron and accessory building occupy an area of over 1000 sq.m. There are also five small greenhouses and a special greenhouse for photo-periodic work, their total area being about 1000 sq.m.

At present the Institute is a large scientific research center rich coordinates work on plant physiology carried out in many scientific institutions of the Soviet Union. The Institute has made significant contributions to the development of plant physiology in the Soviet Union and abroad. By its recommendations it has made its contribution to the national economy of the country. For its work in the development of biology and the training of highly qualified scientific workers the Institute was awarded in 1969 the Order of the Red Banner of Labor and its director, Academician A.L. KURSANOV, was honored by the title of Hero of Socialist Labor.

x

Editor's Note: Readers desiring additional or more detailed information about this Research Institute or about the Phytotron should write to the authors at the following address:

Institute of Plant Physiology
Academy of Sciences of the USSR
Botanicheskaya Str. 35
Moscow 127273 USSR

x

x

x

V. CURRENT PLANT BIOLOGY RESEARCH AT BIOTRON UNIVERSITY OF WISCONSIN (USA)
--

T.T. KOZLOWSKI, Director of the Biotron

Editorial Note: We received in 1977 a list of research subjects and publications from the Director of the Biotron. For our readers, we have made an extract of those which deal with plant biology. Persons desiring to obtain additional information should contact the Director of the Biotron at the following address: Biotron, University of Wisconsin, 2115 Observatory Drive, Madison Wisc. 53706. USA.

x

CURRENT BIOTRON RESEARCH

The Biotron is now operating at maximum capacity and has a waiting list of investigators. Pressure for additional space is great and present indications are that this will continue. Two large requests for extensive expansion of current projects were recently declined by the advisory committee.

Because of the current heavy demand for space and facilities, a program of construction of small environment-controlled cabinets has recently been accelerated. These cabinets are being located in modified rooms previously used for storage. The addition of these cabinets will increase the total capacity of the Biotron and free

both plant and animal rooms, for sophisticated experiments requiring programmed environments.

Altitude and High Pressure Chambers

An entirely new dimension has been added to the Biotron with the recent acquisition of two pressure chambers, for medical altitude studies and of ocean depths.

Current Projects on Plant Biology

From general list of current projects we pull out summaries of those on plant Biology.

Protein accumulation in beans grown under defined conditions (B.P.00008) T.C. Hall (Horticulture)

Development of the bean fruit over the three-week period from flowering involves synthesis of large amounts of reserve proteins in seeds. This protein may be resolved into two major regions by disc gel electrophoresis. The objective of this research is to trace the sequence of formation of this protein and determine the relative importance of translocation of metabolites from the leaves to the developing fruit and direct photosynthetic assimilation of CO₂ and subsequent incorporation of the carbon into protein of the fruit. Experiments will be conducted under programmed environmental conditions.

Funds: Graduate School :NSF

Base line growth studies (B.P.3010) T.W. Tibbitts (Horticulture)

This is part of a cooperative study by the American society for Horticultural Science to develop base-line growth curves for selected plant species as a means of upgrading research in growth chambers. Plants will be grown under carefully prescribed procedures and with detailed environmental monitoring during the entire study. Data from separate laboratories will be collated. The base-line growth curves will (1) provide a biological standard for laboratories to check their growing procedure and equipment and (2) provide growth data for representative plant species that can be used as base-line standards for "optimizing" conditions that control plant growth.

Funds: NSF

Genetic modification of seed protein in legumes undergoing biological nitrogen fixation (B.P.3020) F.A. Bliss (Horticulture)

Standard and protein-modified genotypes of *Phaseolus vulgaris* and standard strains (i.e. K26) of *Rhizobium phaseoli* will be used to determine the role of nitrogen substrate on biological nitrogen fixation and the expression of % seed protein and methionine content. A controlled environment will be used. We will determine the limits (both high and low) of seed protein and methionine content that can be attained by altering the nitrogen substrate within the range of levels that are not suppressive either because of a deficiency or an excess of nitrogen. The following questions will be asked:

A. Is biologically-fixed nitrogen as the sole nitrogen source adequate for maximum % protein and methionine synthesis and accumulation when plant growth is adequate in the range of genotypes studied ?

B. What are the important interactions between added nitrogen, nitrogen fixation (nodulation and nitrogenase activity), nitrate reductase activity and seed protein and methionine expression in the range of protein-variable genotypes?

a. Do different sources of nitrogen contribute equally or differentially to seed protein expression?

Standard procedures will be used to determine active nitrogen fixation, nitrate reductase levels, seed protein and methionine content.

Funds: Graduate School

Study of photoperiod and temperature responses of soybean genetic types (B.P.4011)
J.W. Pendleton (Agronomy)

Photoperiodic and temperature responses of four varieties of soybean that performs well in the tropics will be grown in different temperature regimes: one approximating average temperatures in Bogor, Indonesia during the rainy season; one the dry season; and one at high latitudes. Seven treatments will be used in each of three growth rooms, with switching occurring at three growth phases (germination-first flower; flowering; pod filling). Data will be taken on developmental stages (days to flowering, pod formation, and maturity). Yield data will be taken and components of yield determined.

Funds: Midwest Universities Consortium for International Activities (MUCIA)

Air pollution interactions on crop plants (B.P.4027)
T.W. Tibbitts (Horticulture)

Sensitivity of selected crop cultivars to ozone, sulfur dioxide, and nitrogen dioxide alone and in combination will be determined. Fumigations of one to eight hours will be undertaken to determine minimum threshold dosages for carrots, mint, peas, turfgrass, and alfalfa. Threshold levels for individual and mixed pollutants will be determined. Stomatal responses of various cultivars will be monitored during and after fumigation.

Funds: Madison Gas and Electric Co; Wisconsin Power and Light Co; USDA; Wisconsin Service Co. through Institute of Environmental Studies.

Responses of plant growth to unusual conditions (B.P.5019)
R. Levins (Harvard School of Public Health)

This study will investigate patterns of genotype-environment interaction for cultivated plants, weeds, and some non-domestic plants and to characterize their norms of reaction. We will

- a. Determine whether selection for high yield has reduced the range of tolerance of crop plants.
- b. Reveal the latest genetic variability which appears within apparently homogeneous populations under unusual conditions.
- c. Look for variability in the rates of physiological adjustment to environmental change, capacity to hold CO₂ for short intervals, and tolerance for allelopathic substances of weeds.
- d. Examine the feedback of environment on growth habit as affecting micro-environment of the plant.

The genotype as norm of reaction is the central concept of ecologically oriented developmental biology. But it has not been mapped systematically. This study will initiate such a mapping, searching for general rules relating tolerances to ecological history, variances to environment quality, and therefore suggest a strategy for plant selection.

Funds: Harvard School of Public Health; Ford Foundation

Biosynthetic studies of medicinally important alkaloids in higher plants (B.P.6003)
C.R.Hutchinson (Pharmacy)

As a result of four years of research wherein putative radioactively labeled precursors were fed to *Camptotheca acuminata* plants, a probable *in vivo* biosynthetic pathway to camptothecin was outlined (HUTCHINSON, C.R. et al. 1974. J. Am. Chem. Soc. 96: 5609-5611). Additional experiments will be performed to define the sequence of events in the pathway. The experimental approach involves administering specifically labeled OR and ¹⁴C organic compounds to apical plant cuttings and then isolating camptothecin after a suitable metabolic period under controlled environmental conditions. If the alkaloid is radioactive and can be shown to be specifically labeled, the results will be analyzed to vindicate or eliminate certain steps of a hypothetical biosynthetic pathway to camptothecin.

Funds: NIH

Corn investigations--population improvement and utilization for improved northern corn belt hybrids (B.P.6004)
J.H.Lonnquist (Agronomy)

Genetic variability for almost all traits is present in plant populations and especially so in cross fertilized species. The plant breeder's opportunity to take advantage of the variability present depends on his ability to differentiate among plants having a larger than average value for the trait desired and persistence in effecting a reasonable change in the material with which he is working.

In an attempt to develop lines and hybrids capable of germination and rapid early establishment in cold wet soils, germplasm pools having these characteristics are needed. It is believed that, through mass selection, a population having the ability to germinate under unfavorable conditions and grow relatively vigorously can be developed.

A varietal maize composite was formed from open pollinated varieties. This composite has been undergoing random mating and mass selection since 1971. Some 3000 seeds--one seed per pot-- will be planted and groups of 20 pots will be placed in a growth chamber having a programmed temperature regime (10°C at night to maximum of 15°C during the day). Temperature will be increased by 0.5°C per day. When the young seedlings begin to emerge, the first 10% (2/flat) will be transplanted to a field nursery. These will be sib-mated at random to produce the generation to be resampled at approximately the same time next year. After several generations of selections, an evaluation will be made to compare the several cycles of selection to characterize progress per cycle.

Funds: USDA

The use of a controlled relative humidity chamber for air pollution research (B.P. 6008)
A.W.Andren (Water Chemistry)

Aerosols produced by human activities often exceed these natural origin. both in number and mass. It is important to characterize these aerosols. Aerosols are being collected using high volume air samplers as well as cascade impactors. A small, chamber in the Biotron, capable of maintaining constant relative humidity will

will be used to weigh and calibrate aerosols collected over Menominee River Watershed as well as over Lake Michigan

Funds: NOAA Sea Grant;WRC-EPA

Response of different height genotypes of sorghum to two daylengths; (B.P.6012)
S.Solahuddin and P.N.Drolsom (Agronomy)

The effects of photoperiod and genotype, including various combinations of dwarfing genes, on growth patterns and yield of seven varieties will be studied. Photoperiods will represent a tropical climate and a temperature one. The experiment will be conducted in a modified split-plot design with daylength as the main plot and variety as the subplot. Data will be taken on date of emergence, height at 30 days and flowering date, heading date, and yield.

Funds: Midwest Universities Consortium for International Activities (M6C1A)

Bacterial nitrogen fixation to increase crop yields (B.P.6015)
W.J.Brill (Bacteriology)

Under controlled conditions soybean and corn plants will be grown in pots. The soil (or other medium) will be inoculated with bacteria known to fix molecular nitrogen. The genotypes of both the plants and bacteria will be varied in order to identify the most productive combinations. After different growth periods the soils and roots will be analyzed for nitrogenase activities.

Funds: Rockefeller Foundation;NSF

Effects of environmental stress on reproductive development in oats (B.P. 6019)
D.M .Peterson (Agronomy)

Panicles of *Avena sativa* frequently emerge with few sterile florets, presumably as a result of environmental stress. This project will examine (1) the relation between type, severity, and duration of imposed stresses (primarily light and temperature) on recurrence of sterile florets, (2) the developmental stages at which *Avena* plants are most susceptible, and (3) the relationship between kernel number per panicle and yield. The physiological basis of the stress-induced failure of floret development will be evaluated.

Funds: Graduate School

Low temperature effects on meiosis in arborvitae (B.P.6021)
D.T.Lester and C.D.Upper (Forestry;Plant Pathology)

Meiosis in anthers and strobili of most forest tree species in the northern temperate zone occurs in early or mid May when minimum air temperature is usually above -5°C. Scandinavian research shows that temperatures of -6°C result in chromosomal aberrations in species with the typical phenology of meiosis. By contrast, meiosis in arborvitae (*Thuja occidentalis*) occurs in late February when temperatures fluctuate widely above and below 0°C. This study addresses two questions: (a) does meiosis in arborvitae progress at temperatures below 0°C, and (b) can low temperature shock disrupt meiosis ?

The meiotic process will be stimulated by a period of warm days, then followed during a period of temperatures below 0°C. Timing of environmental changes will be determined by daily sampling of microspore development.

At meiotic stages reported to be sensitive to low temperature shock, plant material will be removed from the standard temperature regime and treated at -10°C or -20°C. Sampling will follow to estimate effects. Information in the form of frequency distributions for stages of meiosis and frequency of abnormal microspores will be interpreted in relation to stated objectives.

Funds: USDA.

Germination of northern monkshood (Aconitum noveboracense), and secondarily, associated cliff dwelling species (B.P.7004)

J.H.Zimmerman and R.H.Read (Wisconsin Dept.of Natural Resources)

Aconitum noveboracense is being considered by the Federal Government for protection under the Endangered Species Act. The species is restricted to cliff dwellings and ledges even though it produces copious seeds which are widely dispersed into or near waterways. Attempts to grow plants from seeds in the greenhouse have failed. The objective of this research will be to investigate factors that may influence germination, such as temperature, light intensity, daylength, salt levels and composition, stratification, etc.

Funds: Wisconsin Dept. of Natural Resources; U.S. Army Corps of Engineers

Effects of environmental preconditioning on stomatal responses (B.P.7008) R.R.Kozlowski (Biotron)

The effects of preconditioning by environmental stresses on control of stomatal aperture (and development of leaf water stress) of woody plants under different environmental regimes and changes (light intensity, temperature, and humidity, pollution) will be investigated. Initial experiments will deal with preconditioning effects of air pollution (SO₂, ozone and their interactions). After preconditioning in fumigation chambers, the preconditioning stress will be alleviated and stomatal responses will be studied under programmed daily environment. Responses to sudden changes in light intensity, temperature, and humidity will also be studied.

Funds: Graduate School; NSF proposal pending

Influence of daylength and temperature on tentoxin sensitivity of chloroplast coupling factors 1 (B.P.7012)

R.D.Durbin, Plant Pathology

Most species of plants have or lack a high-affinity site on coupling factor 1 (CF₁) for the phytotoxin tentoxin. The CF₁ of some greenhouse-grown species changes

in its reaction to tentoxin as the plant ages. Present evidence strongly suggests that

this alteration involves a structural modification of CF₁. It may be a response to aging or it may be induced by changing environmental conditions. This project will examine the influence of daylength and temperature on the alteration of CF₁ to tentoxin.

Funds: Graduate School

Studies on temperature effects and photoperiod on nitrogen fixation and flower absorption in Phaseolus vulgaris (B.P.7013)

P.H.Graham, Horticulture (Visiting Scientist)

In studies conducted at Centro Internacional de Agricultura Tropical three factors were associated with wide variability in nitrogen fixation in Phaseolus vulgaris. These were partitioning of carbohydrates, temperature, and length of the preflowering period. Cultivars of Phaseolus vulgaris differed markedly in nitrogen fixation, with determinate cultivars less active than pole cultivars in this capacity.

It has been difficult to isolate and study such differences in field experiments. This present study will study four cultivars, representing different growth habit groups and will determine their nitrogen fixation capability in different temperature regimes, their partitioning of carbohydrates, nodule and root respiration, and flower absorption.

Funds: USAID; Graduate School

Other Biotron Projects (only on plants)

- N° 8003 Leaf movement Rhythms under Controlled Environments. T. TIBBITTS, Horticulture Department Madison.
- N° 9005 Plant Enzyme change related to cold acclimation. T. C. HALL. Horticulture Department Madison.
- N° 9007 The effects of chemicals on transpiration rates and leaf epidermis of plants. K. BUCHHOLTZ, N. HUNBERG Department of Agronomy Madison.
- N° 9016 Dependence of Crown Gall Induction on Nuclear DNA synthesis. E. PATAU. Department of Medical Genetics Madison.
- N° 9019 Improvement of Total Protein and quality of protein in Cowpea Vigna sinensis. T. C. HALL, F. BLISS Horticulture Madison.
- N° 0002 The effect of washing of the wound on the Crown Gall Development. E. PATAU Dept. of Medical Genetics Madison.
- N° 0003 The Inheritance and physiology of efficiency in phosphorus utilization by snap Beans, Phaseolus vulgaris. G. P. WHITEAKER, G. C. GERLOFF, W. H. GAVELMAN. Horticulture Madison.
- N° 0004 Influence of temperature of growth and nitrogen metabolism of corn. L. SCHRADER Agronomy Madison.
- N° 0011 Induction of Normal Microsporogenesis in Solanum tuberosum variety. Chippewa under controlled conditions of temperature light, relative humidity and nutrition. E. SOUTER Biology Beloit College
- N° 0015 Environmental investigations of leaf movements. T. W. TIBBITTS Horticulture Madison.
- N° 0016 Isolation and characterization of Glyoxysomes (peroxysomes) from Cucumber cotyledons. W. M. BECKER Botany Madison.
- N° 0017 Tissue analysis for nutrient assay of Natural water G. C. GERLOFF. Botany Madison
- N° 0019 Effect of circadian rhythm on Host response to virus infection. J. SPLATIN, R. P. HANSON. Veterinary Science Madison.
- N° 0020 Alfalfa Weevil. Fall development under excessively warm temperatures and ambient daylengths. J. LITSINGER, J. W. APPLE Entomology Madison.

- N°0029 Genecology of Thuja occidentalis in Wisconsin R.L.MUSSELMAN, D.T.LESTER. Forestry Department Madison.
- N°0031 The inheritance and physiology of efficiency in phosphorus utilization by Snap Beans Phaseolus vulgaris. R.M.RICE, G.C.GERLOFF, W.H.GABELMAN Horticulture and Botany Madison.
- N°0032 Hormone environment interactions in growth and organ formation of Tobacco tissue cultures. F.SKOOG Botany Madison.
- N°1001 Effect of environment on stomatal response and internal water balance of Fraxinus americana and Acer saccharum seedlings. T.KOZLOWSKI Department of Forestry Madison.
- N°1003 Studies of meiosis, gametogenesis, pollination and fertilization, and zygote development of cowpea, Vigna sinensis. F.A.BLISS and T.A.LADEINDE Horticulture Madison.
- N°1004 The influence of high temperature and water stress on pollination, fertilization and development of onion seed. B.STRUCKMEYER. Horticulture Madison.
- N°1006 Environmental regulation of photosynthesis in Plant Canopies. R.ALDERFER Biology Chicago.
- N°1007 Response of aquatic plants to high temperature and various light intensities. G.C.GERLOFF and G.WOJCIK Botany Madison.
- N°1010 Controlled atmosphere fruit and vegetable storage F.BUELOW and P.SINGH Agricultural Engineering Madison.
- N°1014 Photoperiodic responses for a range of Maize genotypes R.ANDREW Agronomy Madison.
- N°1016 A study of the effects of different light and temperature regimes on differential colonization of tobacco callus tissues and seedlings resistant of susceptible to Phytophthora parasitica var. nicotiana. J.HELGESON Plant Pathology Madison.
- N°1021 Detection and Elucidation of significant growth and yield responses of high plants. F.A.BLISS and all. Horticulture, Agronomy and Botany Madison.
- N°2000 Control of Fungal diseases by Genetic Manipulation of the pathogens. C.D.UPER Plant Pathology Madison.
- N°2002 Effect of temperature and light on growth of Red Oak and development of Oak Wilt. R.D.DURBIN and P.FENN, Plant Pathology Madison.
- N°2007 Role of cotyledons in establishment and growth of seedlings of Woody Plants. T.T.KOZLOWSKI Forestry Madison
- N°2010 Two dimensional soil-water-Plant-Atmosphere Model studies. C.DIRKSEN. Soil Science Madison.
- N°2011 Response of plants to extremely low frequency fields. F.DALTON and all. Soil Science Madison.
- N°2013 Low temperature grain drying. M.FINNER, J.A.BARESCH. Agricultural Engineering Madison.

- 2015 Identification and stability of sudangrass plants very low in HCN Potential.
N P.N.DROLSOM Agronomy Madison.
- 2022 The influence of soil temperature on plant growth and survival.B.H.Mc GOWN
N Horticulture Madison.
- 2023 Optimization of the environment for space plants.T.W.TIBBITTS Horticulture
N Madison.
- 3005 The effects of seed source and seedling uniformity on Wilt development of
N Red Oak seedlings.P.FENN and all.Plant Pathology Madison.
- 3007 Effect of wind on stomatal aperture and transpiration of Fraxinus americana
N and. Acer saccharum seedlings.T.T.KOZLOWSKI and W.J.DAVIES Forestry Madison
- 3011 Effect of environment of water relations of woody plants.T.T.KOZLOWSKI and
N J.PEREIRA Forestry Madison.
- 3012 Is a single dominant gene conferring disease resistance to intact tobacco
N plants expressed in Tobacco tissue cultures? J.P.HELGESON Plant Pathology Madison.
- 3016 Base line growth studies.T.W.TIBBITTS Horticulture Madison.
N
- 3017 Effect of atmospheric CO₂ concentration on levels of carbonic anhydrase in
N plants S.B.KU and G.E.EPARDS Horticulture Madison.
- 3018 Long term effects of environment on solanum tuber production.B.H.Mc GOWN
N Horticulture Madison.
- 4002 Nutrient runoff from agricultural land following winter manure applications.
N G.D.BUBENZER Agricultural Engineering Madison.
- 4006 Differentiation of Erwinia cartovora and E.atroseptica S.H.DEBOER and A.KELMAN
N Plant Pathology Madison.
- 4007 Verification of pollution monitoring equipment under varying environmental
N conditions.Dept Natural resources Madison.
- 4008 Growth of soybeans under tropical conditions.H.A.SENN Biotron Madison.
N
- 4011 Study of photoperiod and temperature response to soybean genetic types.
N J.W.PENDLETON Agronomy Madison.
- 4014 Effects of temperature and photoperiod on growth and hardiness of four western
N conifers.P.W.OWSTON Forest Service Corvallis Oregon.
- 4021 Modification of frost sensitivity of corn.Physiological and Genetic.D.L.ARN
N Y and C.D.UPPER Plant Pathology Madison.
- 4022 Isotope discrimination in CAM plants.R.H.BURRIS Biochemistry Madison.
N
- 4025 Comparison of vigor and agressiveness of two different ecotypes of nature
N grass species.D.G.MORRISON and A.ANDERSON Landscape Architecture Madison.
- 4027 Air pollution interactions on crop plants.T.W.TIBBITTS Horticulture Madison.
N

- N°5011 Influence of weather on herbicide susceptibility of corn.R.G.HARVEY Agronomy Madison.
- N°5004 Studies on cytogenetics and breeding technique with Eragrostis tef (Zucc.) Trotter.M.ASSEFA Agronomy Madison.
- N°5012 Photosynthetic and respiration rates of Pinus flexilis seedlings under drought stress and various temperature acclimations. M.G.LEPPER Botany Madison.
- N°5013 The effect of hard frost on the Phytotoxicity and translocation of glyphosate in Quackgrass and Alfalfa.H.E.DAVIS and R.S.FAWCETT Agronomy Madison.
- N°5014 Development of predictive index to determine relative susceptibility of potato tubers to soft rot Bacteria.A.KELMAN Pathology Madison.
- N°5015 Biosynthetic studies with C-13/C-14 CO₂ of Medicinally important alkaloids in higher plants.C.R.HUTCHINSON Pharmacy Madison.
- N°5019 Responses of plant growth to unusual conditions.R.A.LEVINS.Harwardschool Boston.
- N°5021 Effects of light and temperature on one association between corn and Spirillum lipoferum.R.H.BURRIS Biochemistry Madison.
- N°6003 Biosynthetic studies of Medicinally important alkaloids in higher plants. C.R.HUTCHINSON Pharmacy Madison.
- N°6004 Corn investigations.Population improvement and utilization for improved Northern Corn Belt hybrids.Selection for germinability and Early Growth under cold wet conditions characteristic of Planting seasons in North central Wisconsin.J.H.LONNQUIST Agronomy Madison.
- N°6007 Precocious germination in cultured barley embryos.K.NORSTOG.Biological Sciences Dekalb.
- N°6008 The use of a controlled relative humidity chamber for air pollution research. A.W.ANDREN.Water chemistry Program Madison.
- N°6012 Response of different height genotypes of sorghum to two Day lengths.S.SOLAHUDDIN and P.N.DROLSOM Agronomy Madison.
- N°6014 Cockroach Trapping with Attractant Sticky traps.W.E.BURKHOLDER and A.BARAK Entomology Madison.
- N°6015 Bacterial nitrogen fixation to increase crop yields.W.J.BRILL Bacteriology Madison.
- N°6018 Effects of light and relative humidity on stomatal aperture of Populus clines T.T.KOZLOWSKI and S.G.PALLARDY Forestry Madison.
- N°6019 Effects of environmental stress on reproductive development in oats.D.A.PETERSON Agronomy Madison.

- N°6021 Low temperature effects on Meiosis in Arborvitae D.T.LESTER and C.D.UPPER
Forestry Madison.
- N°6023 Ovipositional preference and survival of Diptera Agromyzdae on three Cruciferous
plant.S.J.TAVORMINA and all.Zoology Madison.
- N°7001 A study of the behavior and population biology of vespine social Wasps in
Wisconsin.R.L.JEANNE Entomology Madison.
- N°7004 Germination of Northern Monkshod (Aconitum noveboracense), and secondarily ,
associated cliff dwelling species.J.H.ZIMMERMAN, R.H.READ Natural Resources
State Wisconsin.

x

VI. THE PLANT GROWTH ROOMS AT THE DEPARTMENT OF PLANT HUSBANDRY

U.WUNSCH.Dept.of Plant Husbandry, Agricultural College of
Sweden S 75007 Uppsala 7-Sweden.

Editorial Note: The information given below is an extensive summary of Report n°65,
Uppsala, 1977. Persons wanting more information should contact the College of
Agriculture directly.

Introduction.

Since 1968, when the laboratory building was completed, nine plant growth
rooms have been available.In addition to these growth rooms, the department also has
other facilities for plant growth experiments under more or less controlled
environmental conditions.A list of available spaces and facilities is given below:

1.An outdoor pot experiment cage.35 x 35 meters, covered by metal net.Space for 2000
pots, e.g.Mitscherlich pots.

2.Three greenhouses.Each greenhouse is 5 x 14 meters and has a bench space of about30M²
There is equipment for controlling day and night temperature and air humidity.However,
because of intense sunshine it is often impossible to keep the air temperature below
25°C during the summer, even though the greenhouses are cooled by sprinkling water on
the outside of the glass roofs.Supplementary light can be given by means of fluores-
cent tubes.

3.Nine plant growth rooms, described in this report.

4.Three plant growth cabinets, described earlier by Winsche (Annals of Agricultural
College of Sweden 1966, 32, 417-426).

5.Twelve light thermostats.These are small growth cabinets, four with the
dimensions 55 x 55 x 75 cm and eight with 40 x 40 x 55 cm.They are equipped with
fluorescent

tubes giving approximately 40 W per m². Daylength and day and night air temperature can be controlled, but so far not air humidity.

6. Seven temperature controlled rooms. 2.5 x 1.9 meters. Air temperature can be controlled with an accuracy of + 1°C from -5° up to + 40°C. No control of air humidity. There are no light sources for plant growth. The rooms are intended for experiments in darkness or very low light intensities, germination experiments or storage of plant material under constant temperature conditions.

The department also has special equipment and rooms for germination tests such as the Jacobsen apparatus and small thermostat-controlled cabinets. For freezing and cold-hardiness tests a chryostate is available giving temperatures down to -40°C.

In this report the plant growth rooms will be described in more detail in order to provide further information about the technical equipment and the environmental conditions beyond the data, often limited, usually given in research reports on experiments performed in these growth rooms.

The term "plant growth room" has been used according to Downs (Controlled environments for plant research. Columbia University Press New York and London 1975 175 pp), describing artificially lighted rooms in which temperature, relative humidity and sometimes other environmental factors are maintained at a fixed level or varied according to a predetermined programme. Plant growth rooms are large enough to admit an operator and usually exceed 2.8 m². Smaller reach-in units less than 2.8 m² are usually called plant growth cabinets.

1. GENERAL DESCRIPTION

The plant growth rooms were delivered and installed by AB SVENSKA Flaktfabriken during 1967-69. They are placed in the basement of the laboratory building together with seven constant rooms according to the plan given in Fig. 1.

Desired specifications

A good plant growth room has the following main requirements:

- (a) Environmental conditions uniform in space and time.
- (b) Defined and reproducible conditions which foster plants similar to plants in a typical natural climate.
- (c) Possibility of varying daylength and night temperature according to a predetermined programme.
- (d) Interior dimensions giving large enough usable space and admitting an operator.

These requirements are certainly very vaguely formulated and hence in addition the following specifications were given to the manufacturer.

Temperature. A temperature range of + 5° to + 40°C was considered a realistic specification. Knowing the technical difficulties and high costs to maintain lower temperatures + 5°C was accepted as the lower limit, especially as the department has other facilities for cold-hardiness and freezing experiments. Higher temperatures than + 40° are scarcely of interest for plant growth experiments.

A maximum temperature variation of + 0.5°C in space and time was desired. Consi-

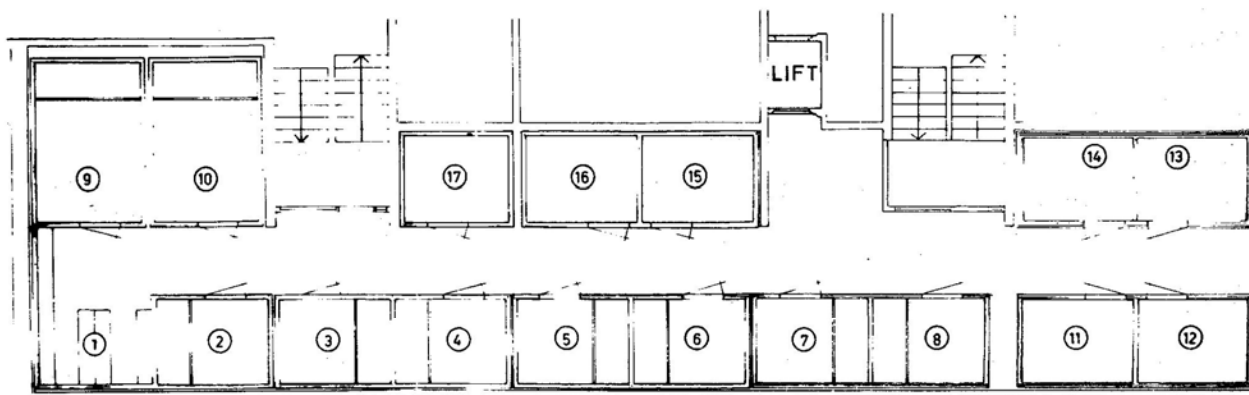


Fig. 1. Plan of the plant growth rooms and the temperature controlled rooms in the basement of the laboratory building of the Department of Plant Husbandry.

- 1. Control panels with electronic regulators etc. (cf. Figs. 4 and 5)
- 2- 8. The seven smaller plant growth rooms.
- 9-10. The two larger plant growth rooms.
- 11-17. Seven temperature controlled rooms.

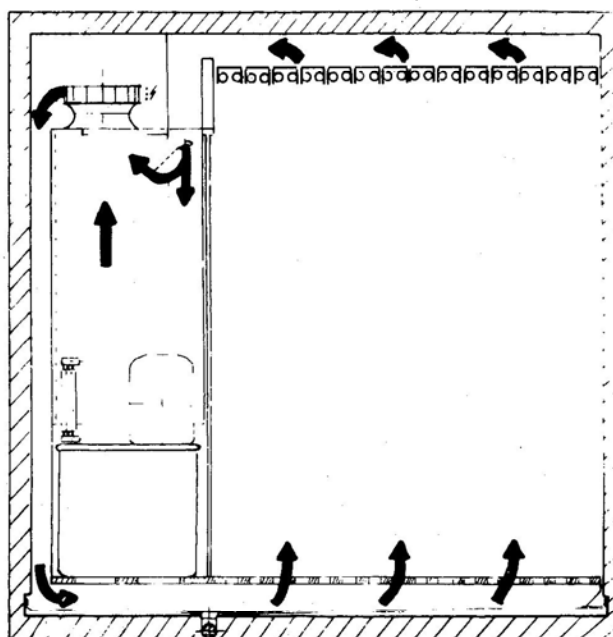


Fig. 2. Front section of a plant growth room showing the air circulation through the air conditioning unit and the growth room.

Relative humidity.The range in relative humidity was not specified other than "as low as possible" and "as near 100% relative humidity as possible".It was considered unrealistic to require a smaller variation in space and time than + 5%.

Ventilation.A makeup air system was required to give a sufficient amount of fresh air in order to prevent a carbon dioxide depletion of the air.

Light.As high a light energy as possible within the range of photosynthetically active radiation (i.e.visible light between 400 and 700 nm) was desired and means of varying the light intensity and the light period.In addition to the visible light a smaller proportion of infrared radiation (i.e.wave length over 700 nm) was wanted in order that the plants should have a normal development.

Description of the growth rooms

Each unit consists of a growth room and a room for air conditioning equipment separated from each other by sliding doors which can be removed.

The internal size of the growth rooms is
1.7 x 1.9 m (seven smaller rooms) and
2.4 x 2.6 m (two bigger rooms)

The units are built of wooden frames covered on the in-and outside with aluminium sheets with insulating material in between. The inside walls were painted white. The growth rooms have one door, 0.80 x 1.94 m, insulated with rubber strips.

The bottom of the room is covered with a plastic material.This floor has a downward gradient for drainage of water.The plastic flooring is covered by wooden duckboards which are in turn covered by a perforated aluminium floor through which the air is let into the growth rooms (Fig.2).

The air is evacuated from the growth room through slits between the fittings for the fluorescent tubes in the ceiling.Each fitting has two fluorescent tubes mounted under a reflector, painted white, with the ballast on the upper side.It is, of course, a disadvantage to place the ballasts in the growth room as they load the room with extra heat. However, there was not enough space for them outside the growth room. On the other hand, placing them directly on the fittings for the fluorescent tubes also made the electrical wiring easier.Unfortunately the low height of the ceiling in the basement where the growth rooms are placed did not permit enough space for a plexiglass barrier under the fluorescent tubes.

2. AIR CONDITIONING AND THE CONTROL OF AIR TEMPERATURE AND RELATIVE HUMIDITY

Each growth room has its own equipment for air conditioning.It consists of 4 water basin with a circulation pump, cooling coils and electrical heat cartridge, refrigerating compressor with a water-cooled condensor, two air conditioning towers with a water sprinkler, contact material made of specially impregnated corrugated cardboard, by-pass throttle, circulating fan and electrical air heater.

The unit works mainly with circulating air.However, air from outside is introduced in order to maintain the carbon dioxide content on a sufficiently high level. The growth room is kept slightly pressurized which prevents uncontrolled air from leaking into the growth room and disturbing the desired environmental conditions.

Functioning

The circulating air returns together with air from outside the growth room to the conditioning unit and is sucked through the conditioning towers through the by-pass throttle. The two amounts of air are then mixed before they are blown in under the floor of the growth rooms (Fig.2). The proportions of the amounts of air passing through the conditioning towers or the by-pass throttle are regulated by means of the regulating motor of the by-pass throttle which strives to maintain the desired temperature of the mixed air.

The air passes upwards in the conditioning towers where it comes into contact with the water from the basin. This water is cooled or heated before it is pumped to the sprinkler in the top of the conditioning towers. After passing downwards in the tower the water returns to the water basin.

The air temperature and humidity is regulated by means of two electronic control units, one for the "dry temperature" and one for the dew point temperature. The sensor for the dry temperature is placed behind the wall of the conditioning towers.

If the air temperature is falling the by-pass throttle is opened gradually. If this is not sufficient -e.g. when the lamps are switched off in the growth room- the air heating battery is turned on gradually by means of a rotary transformer. If the air temperature is rising the unit will operate in the opposite way.

The dew point thermostat senses the dew point temperature of the air and the sensor is placed in the top of the conditioning tower where the air contains 100 per cent humidity. The thermostat sends an impulse to the water-cooling refrigerator to start if the temperature is rising. If the dew point temperature is falling, the thermostat will send an impulse to switch on the water heater.

Each growth room has a safety thermostat which switches off the electricity to all motors, heaters and lamps if the temperature in the growth room rises to a level that could damage the plants or spoil the experiment in another way.

Programme

A 24-hour programme for the dry air temperature and for the dew point temperature is cut out on two aluminium discs which are *placed* in the electronic control units. The dew point temperature for the desired relative humidity at a certain dry temperature is calculated with the help of a Mollier diagram.

3.LIGHT SOURCES

In the original design each of the smaller growth rooms have 24 fluorescent tubes. General Electric PG, cool white, 160 W. The two bigger growth rooms have 32 tubes of the same kind, 215 W. In order to provide the plants with a small amount of red light with a wave length above 700 nm, four incandescent lamps, 100 W or less, are mounted in each room on the walls under the fluorescent tubes. This set-up of light sources gives an installed power of about 1200 W per m².

The light intensity can be varied by means of step control with 1/3, 2/3 or 3/3 of the lamps lit.

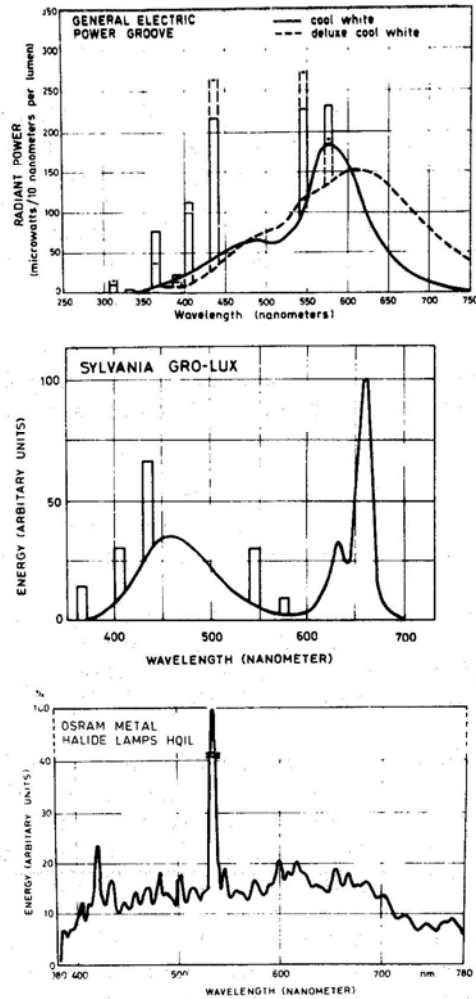
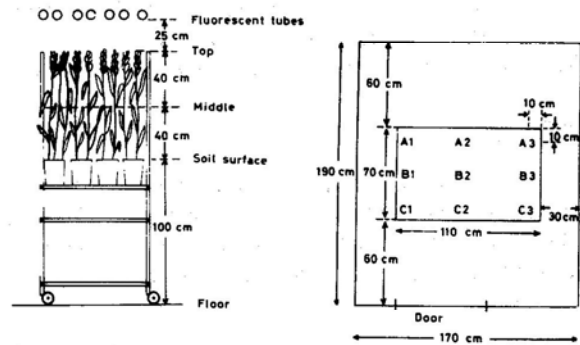


Fig. 7. Spectral energy distribution of four kinds of light sources which have been used in the plant growth rooms.



TEMPERATURES °C:

	TOP			MIDDLE			SOIL SURFACE		
	1	2	3	1	2	3	1	2	3
A	20.6	20.8	20.6	20.8	20.8	20.6	20.0	20.2	20.0
B	20.8	21.0	20.8	20.8	20.6	20.6	20.4	20.2	20.0
C	20.8	20.8	20.8	20.6	20.4	20.4	20.2	20.4	20.2

TEMPERATURE AT FLOOR LEVEL 20.0° C

Fig. 10. Temperature variations at three levels of a "canopy" of wheat plants at a set point of 20° C measured with an Assman psychrometer.

Since 1973 other light sources than the General Electric PG-tubes *also* have been used , e.g. Sylvania. In one of the small growth rooms nine metal-halogen lamps (Osram) have been used since 1976. The spectral energy distribution of some light sources used in the growth rooms are shown in Fig. 7.

4. CULTURAL PRACTICES

The plants are usually grown in plastic pots of various sizes. Different types of soils are used or in some cases other substrates such as peat moss, sand or perlite. Deionized water is used for watering.

In some experiments the plants were grown in aerated nutrient solution according to Wansche (Influence of 2-chloroethyl trimethylammonium chloride (CCC) on two Swedish wheat varieties. *Vartodling Plant Husbandry* 25, 1970).

The pots are placed on carts made of aluminium pipes and with a bench of aluminium net which can be adjusted in height. These carts were built at the Department of Plant Husbandry and were designed to fit into the two types of growth rooms.

5. ENVIRONMENTAL MEASUREMENTS

Temperature and relative humidity

Before the growth rooms were ready for use they were tested according to a special programme as regards temperature and relative humidity. The purpose with this testing programme was to find out whether the desired maximum and minimum values of temperature and humidity could be reached and if the desired maximum variations could be kept

The air-conditioning units and the electronic programme units were also checked in order to see how fast temperature and humidity could be changed from one value to another. In these delivery tests thermohygrographs were used and the instruments were placed on the floor in the center of the growth room. Each thermohygrograph was calibrated against an Assman psychrometer and this instrument was also used to continuously check the temperature and relative humidity in the growth rooms during the test periods.

Later, temperature and relative humidity have been measured at different place in the growth rooms in order to check the variation in space: An Assman psychrometer was also used in these cases.

In an empty growth room and at a set point of 20°C (dry temperature) the variation between different places in the growth room was less than + 0.2°C, which is well within the desired limit of + 0.5°C. However, when the growth room is more or less filled with plants, the trays with the pots and the plants will slow down the air

flow and lead to larger variations than in an empty chamber. This is shown in an example (Fig. 10) where the temperature was measured at the floor level and at different levels among the plants. As can be seen from the figures, the variances in this case sometimes exceed + 0.5°C.

Light

The light energy has been measured with a Moll-Gorczynski solarimeter. This instrument of course does not only give the energy of photosynthetic active radiation or PAR, i.e. visible light, but also radiation with wave lengths shorter than 400 nm and longer than 700 nm. Radiation with wave lengths shorter than 400 nm is not produced by the light sources (fluorescent tubes and incandescent lamps) used in the growth rooms. However, part of the radiant energy emitted from the incandescent lamps has wave lengths longer than 700 nm. Therefore it would also have been of interest to measure the light energy with a filter sorting out this infrared radiation.

Fig.11 illustrates the total radiant energy at two levels in a growth room with the fluorescent tubes as well as the four incandescent lamps lit, and Fig.12 shows the same situation but with the incandescent lamps switched off. The energy flux was measured at 25 places evenly distributed in the horizontal plane (Fig.13).

Fig.11 A shows that the incandescent lamps had a strong influence on the energy, giving peaks under the lamps at the 0.5 level in the two front corners and at two places near the wall opposite the door (compare with the placing of the incandescent lamps, Fig.13).

At a distance of 1 m from the fluorescent tubes the incandescent lamps had *less* influence on the energy flux (Fig.11 B) and the energy distribution was more like the situation when the incandescent lamps were switched off (Fig.12 A and B). In these cases the energy flux was highest in the centre of the room and lowest in the corners.

The highest energy flux at the level of 0.5 m from the fluorescent tubes was 139 W/m² when the incandescent lamps were lit and 102 W/m² when they were switched off. The lowest energy flux at the same level was 108 W/m² (incandescent lamps lit) and 60 W/m² (incandescent lamps switched off).

Carbon dioxide

The carbon dioxide content of the air was measured during a 24-hour period in a growth room in which 50 3-litre pots with six wheat plants in each were placed. The plants were about 40 days old and had reached a length of about 0.5 m. Air was sucked from the growth room through a hole in the wall and led to an infrared gas analyzer. The recording is shown in Figure 14. During the light period the CO₂ content was about 300 ppm and rose to about 400 ppm during the night due to respiratory CO₂ production. The CO₂ content of the outdoor air was 350 ppm. The diagram also shows the strong influence on the CO₂ content of people working in the growth room.

Air flow

The direction of the air flow in an empty growth room has been studied by means of smoke (titan tetra chloride). It was found that the air does not pass vertically upwards through the growth room. Due to the "Quantla effect" (1) the air flow from the floor tends to move towards the walls. It could also be demonstrated that there *was* turbulence in some parts of the room so that the direction of the air flow was approximately as shown in Fig.15.

The air velocity was measured at different sites with a hot-wire anemometer and the values are given in Table 1.

In cases where two values are given *the* air velocity was not steady, and the lowest and highest velocity were noted.

In a plant growth room in which a cart with wheat plants (similar to those in Fig.10) was placed the air velocity above the plants was 0.05 - 0.2 m/s.

(1) The "Quanda effect" means that if air passes along a flat surface it will be attracted by this surface.

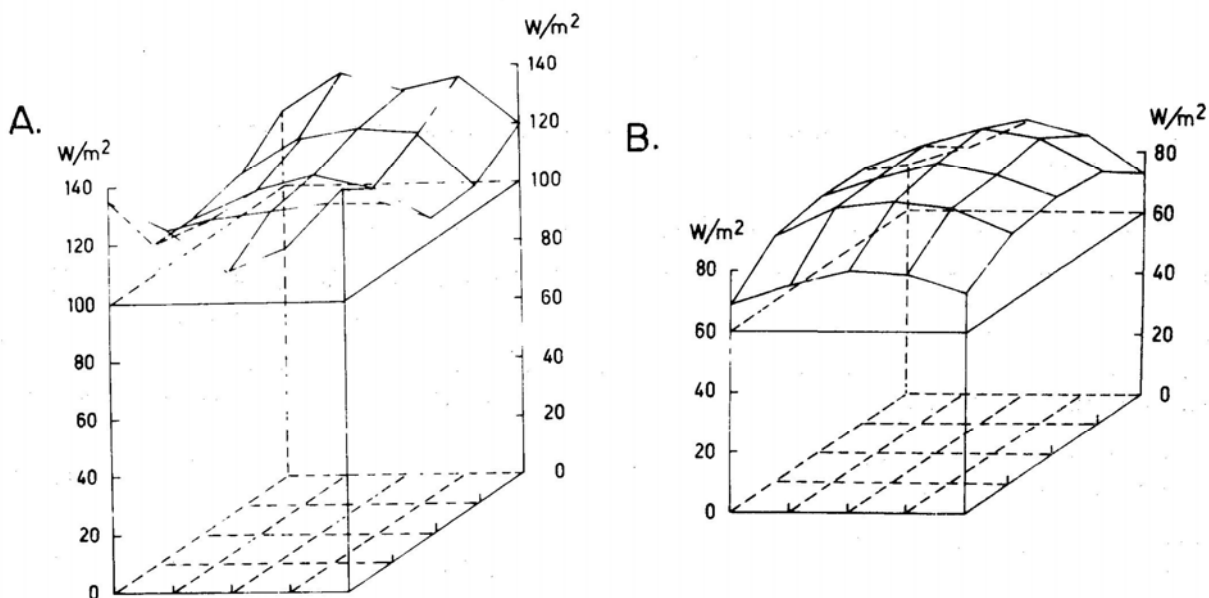


Fig. 11. Horizontal distribution of the radiant energy flux in a plant growth room measured at two levels with a Moll-Gorczynski pyranometer. All fluorescent tubes and incandescent lamps lit.

The lamp set-up was: 15 General Electric PG, Cool white, 160 W
9 Sylvania Gro Lux, 160 W
4 100 W incandescent lamps

The fluorescent tubes had been used for about 5000 hours.

A. At a distance of 0.5 m from the fluorescent tubes.

B. At a distance of 1.0 m from the fluorescent tubes.

(The measuring points in the horizontal plane can be seen in Fig. 13.)

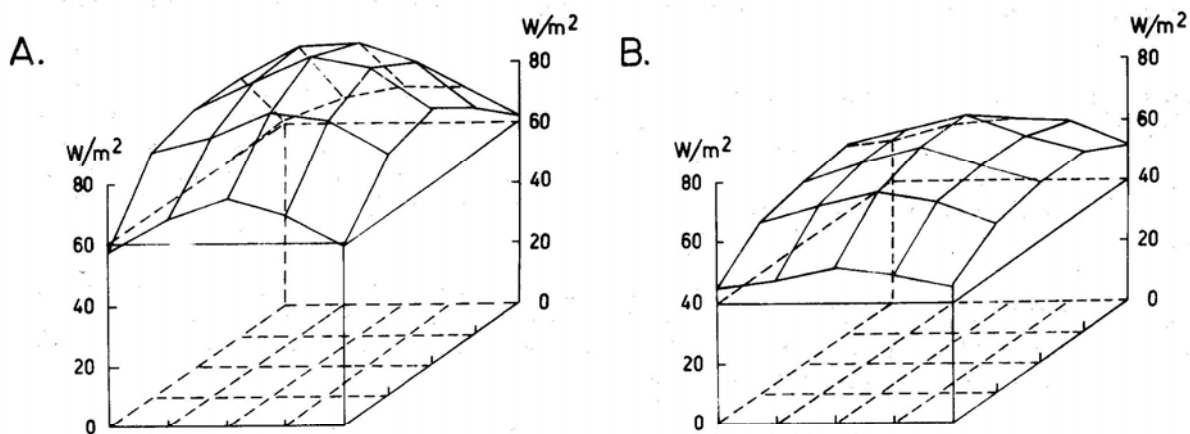


Fig. 12. Horizontal distribution of the radiant energy flux in the same growth room as in Fig. 11 and with the same lamp set-up but only the fluorescent tubes lit.

A. At a distance of 0.5 m from the fluorescent tubes.

B. At a distance of 1.0 m from the fluorescent tubes.

Table 1. Air velocity in an empty plant growth room measured with a hot-wire anemometer.

Place of measurement	Air velocity, m/s			
	Distance from the floor, m			
	0.05	0.5	1.0	1.60
Centre of the growth room	0.90	0.12-0.20	0.08	0.08-0.1
Centre of the wall against the air conditioning unit	0.90	0.90	0.55	0.21
Centre of the wall opposite the door	0.60	0.50	0.50	0.35
Centre of the wall opposite the conditioning unit	0.50	0.35	0.10	0.05

6. DISCUSSION

The plant growth rooms at the Department of Plant Husbandry have now been in use for nine years. On the whole they have functioned satisfactorily. Of course there have been some disturbances, but since most of the equipment consists of standard components there have been few problems in repairing or replacing defect parts. For example, the electronic regulators for control of the dry air temperature and the dew point temperature are standard equipment used for temperature control in buildings and are easily replaceable.

Some of the most common defects have been: ballast failure, failure of the electronic system, pump and fan failure and failure of the electric motor controlling the by-pass throttle.

Ballast failure occurs rather often and is caused by the fact that the ballasts are mounted on top of the fittings for the fluorescent tubes in the ceiling of the growth rooms. If the air temperature and/or the relative humidity is high in the growth room there is a great risk that the ballast will be overheated or damaged by the humidity. But, as mentioned earlier, there *was* no other way of placing the ballasts and thus we have to accept their frequent replacement.

The electronic systems have also failed frequently. Although the electronic regulators (Novotherm) are easy to replace they have been one of the most expensive failures. The manufacturer (BILLMAN Regulator AB) has not been able to explain the cause of these frequent malfunctions of the Novotherm regulators.

The water pumps have been replaced or repaired seven times which must be considered normal for nine pumps during nine years use.

Fan failures are very expensive to repair but have occurred, on the other hand, only three times.

The electric motors controlling the by-pass throttle have had breakdowns three times.

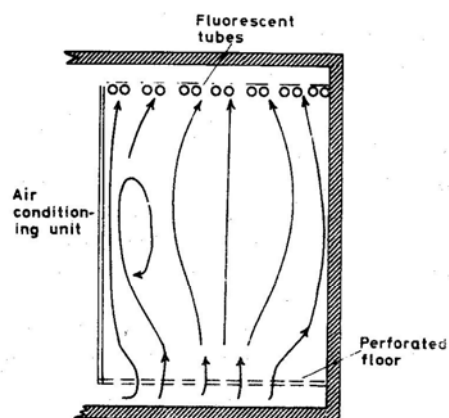
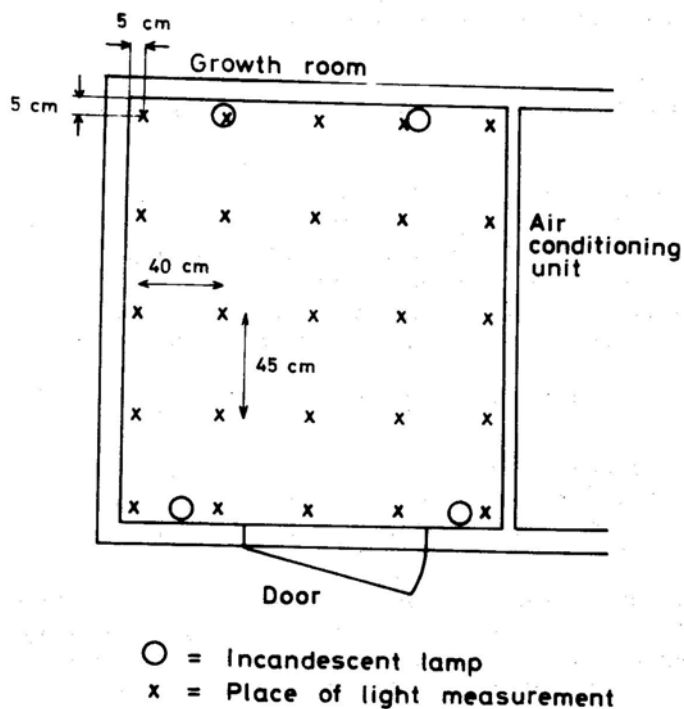


Fig. 15. The approximate direction of the air flow in a plant growth room demonstrated with the help of titan-tetra chloride smoke.

Fig. 13. The placing of the incandescent lamps and the points in the horizontal plane where the radiant energy flux was measured and given in Figs. 11 and 12.

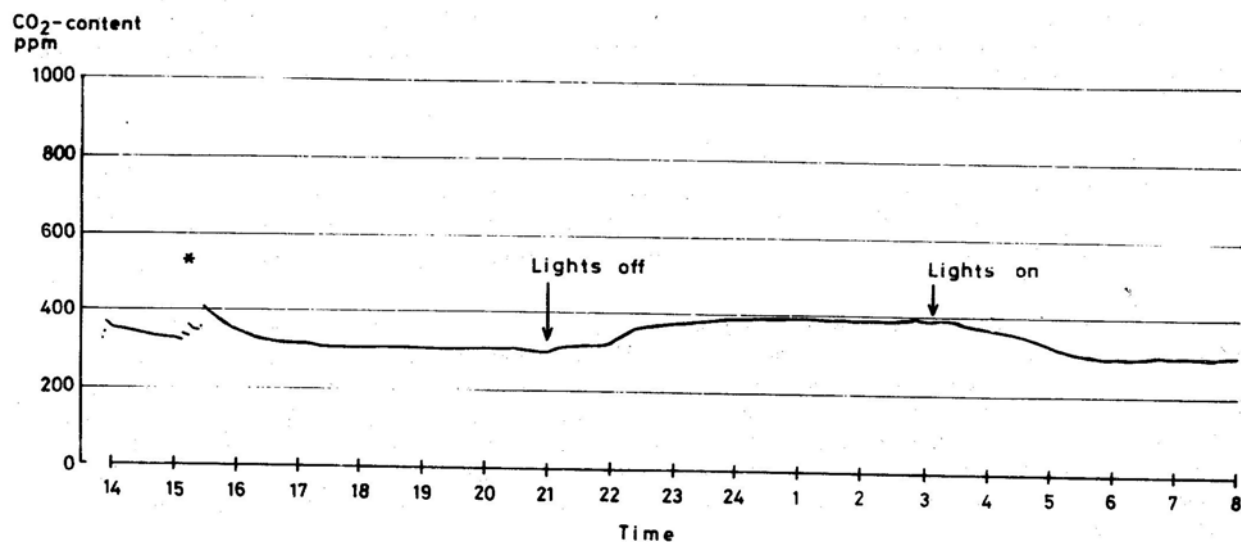


Fig. 14. The carbon dioxide content of the air in a plant growth room during a 24-hour period. The growth room was filled with 300 wheat plants of about 0.5 m height. The CO₂-content was measured with an infrared gas analyzer.

* Technician in the growth room.

Leakage of the water basins has occurred three times. Although the basins are made of stainless steel, vibrations from the refrigerator compressors cause the weldings to fracture.

The refrigerating system has usually functioned satisfactorily. Leakage has only occurred once.

The refrigerators have water-cooled condensers. The cooling water is circulated through all nine condensers and up to the heat-exchanger (a water tower) on the roof of the laboratory building. During the first year the water pressure sometimes dropped below the designed level or the water temperature rose above the maximum temperature permitted ($+ 27^{\circ}\text{C}$), thus causing malfunction of the refrigerating system. The pump has been replaced by a more effective one and these failures have not recurred.

Normally we try to plan our experiments so that at least one growth room is kept empty in case of breakdowns.

The safety thermostat can be connected to an alarm system. During working hours an alarm bell rings if the temperature rises above the set point on the safety thermostat. At other times the system can be connected to a telephone which will ring the investigator at his home (System Securitel).

Since 1968 the growth rooms have been used for many different research projects. Some examples of experiments carried out in the plant growth rooms are given in Appendix B. and experience gained in these experiments will be taken up in the following discussion concerning the importance of controlling major environmental factors. Some biological aspects are also given.

Temperature

As shown in Fig.10 the temperature variation from the set point is larger than $+ 0.5^{\circ}\text{C}$ when there are plants in the growth room. However, if the plants are circulated on the trays or if the places of the charts- are changed regularly at least once a day we find that the variations in temperature will have little or no influence on the uniformity of plant growth. In cases where temperature effects are studied, the differences between the growth rooms is usually 5°C or more and a variation within each growth room less than $\pm 1^{\circ}\text{C}$ will scarcely have any influence.

Light

The light energy flux in a plant growth room depends on: the type, number and age of the light sources; distance from the light sources and location in the horizontal plane (cf. Figs.11 and 12); air temperature (particularly with regard to fluorescent tubes).

In our plant growth rooms the radiant energy flux is usually measured in the centre of the room at plant level before every experiment and often several times during the experimental period. Depending on the air temperature in the growth room and how many hours the fluorescent tubes have been used, we usually find differences in energy flux between the rooms at the same distance from the tubes. This can be adjusted by replacing some of the tubes and/or altering the distance of the plants from the tubes so that the radiant energy flux in the centre of the growth room will be the same in all rooms at plant level.

We are well aware of the rather wide variation in energy flux in the horizontal plane of the growth room (Figs.11 and 12). This is another reason for circulating the plants every day on the trays. In this way it has been possible to get plants of very uniform growth.

As mentioned earlier, much of the radiant energy from the incandescent lamps falls outside the photosynthetic active radiation or PAR. Therefore it would be of a great interest in the future to measure the energy flux with a pyranometer equipped with a filter that sorts out wave lengths above 700 nm (cf. RODSKJER N. Experimented.

investigations into the attenuation of solar radiation in field crops with special regard to the 0.3-0.7 nm spectral band. Vaxtodling Plant Husbandry 27, 1972) or with an instrument giving the PAR quantum flux in micro Einsteins (Mc CREE K.J. Test of current definitions of photosynthetically active radiation against leaf photosynthesis data. Agric. Meteorol. 1972, 10, 433-453).

Carbon dioxide

Our measurements showed that the CO₂ content of the air decreased by about 50 ppm during the light period compared with the outdoor air if the growth room is loaded with as many big plants as the space permits. This CO₂ decrease is not bigger than in a normal field crop canopy (KRZYCH G. 00 Houshalt und Stoffbildung lines Beta Rubenstandes. Z. Acker und Pflanzenbau 1972 i36, 55-84, HARPER et al. Carbon dioxide and the photosynthesis of field crops. A tracer examination of turbulent transfert theory. Agronomy Journal 1973, 65, 574-578). It should also be pointed out that the growth rooms are not normally loaded with as many plants as in the experiment demonstrated in Fig. 14.

It may seem unexpected that the CO₂ content does not drop further. The rather small amount of fresh air added to the circulating air (20 m³/h) would not be enough to keep the CO₂ content of the air on the level shown in Fig. 14. The explanation might be that additional carbon dioxide is entering the growth room by diffusion through the air intake.

Air flow

As shown in Table 1 the air velocity varies considerably between different places in the growth room. However, the importance of the air flow should not be overestimated. Of course, the air flow will influence such environmental factors as temperature, humidity and CO₂ content but each of these parameters are measured separately. If they show satisfactory values this shows that the air velocity is the right from this point of view. On the other hand it should not be forgotten that the air flow affects the leaf temperature (through convection) and transpiration and photosynthesis (through water or CO₂ diffusion).

Despite the relative simple set-up in the growth rooms at the Department of Plant Husbandry in comparison with the more sophisticated climate chambers and phytotrons found elsewhere, we have found them to be of great value in our research work and they have given satisfactory and reproduceable results.

Summary

Nine plant growth rooms are described. They have been in use at the Department of Plant Husbandry since 1968.

A technical description is given (technical data are summarised in Appendix A) and the functioning of the air conditioning system is discussed.

The major environmental parameters: temperature, relative humidity, light, carbon dioxide content of the air and air flow have been measured at different sites in the growth rooms. The importance of the variation of these factors as well as some biological aspects is discussed. The discussion also deals with the causes of some common malfunctions of the plant growth rooms.

Appendix A: Technical Data (according to enclosure to offer from Svenska Flaktfabriken)

Plant Growth Rooms	N ° 2-8	9-10
Outer size		
length	2.7	3.9 m
width	2.1	2.55 m
height	2.7	2.7 m
Inner size of plant growth room		
length	1.7	2.5 m
width	1.9	2.35 m
height	2.0	2.0 m
volume	6.5	12.0 m ³
Light sources fluorescent tubes	4.45	7.9 kW
incandescent lamps	0.4	0;4 kW .!
Fresh air intake	20	40 m ³ /h
Air circulation	3000	5000 m ³ /h
	= 460	420 times/h
Air velocity	0.25	0.24 m/s
Temperature gradient	2.2	2.0 °C
Fan power	1.1	1.1 kW
Pump power	0.74	0.74 kW
Refrigerating compressor	3.0	3.75 kW
Air heater	3.7	6.75 kW
Water heater	2.2	3.75 kW
Cooling requirements	7500	11250 kW/h
Surrounding room temperature		
maximum	+25	+25 °C
Condensing water:cooling tower	+27	+27 °C
Electrical power, voltage	220/380	220/380 V
frequency	50	50 Hz

Appendix B: Examples of experiments carried out in the plant growth rooms at the Department of Plant Husbandry.

1.Environmental effects on germination :

HAKANSSON S.: Germination ecology of weed seeds (unpublished)

HAKANSSON S. & SVENSSON Ch.:Investigations on the germination of pasture seeds (unpublished).

2.Environmental effects on Plant development and growth:

- HALLGREN E.Development of stands of ley plants and weeds at different spacing, distribution and relative time of emergence of the ley plants.Reports and dissertations from the Department of Plant Husbandry, Agricultural College of Sweden, n 9 , 1974 (In Swedish with an English summary).
- HAKANSSON S.Experiments with Agropyron repens (L.) Beauv. VII.Temperature and light effects on development and growth.Annals of the Agricultural College of Sweden, 35, 953-987, 1969.
- JONSSON N.Reserve substances in forage grasses-studies of factors influencing accumulation and utilization of reserves.Reports and dissertations from the Department of Plant Husbandry, Agricultural College of Sweden, n 45, 1976 (in Swedish with an English summary).
- STECKO V.Experiments with simazine, monuron and bromacil-three soil-applied herbicides. Reports and dissertations from the Department of Plant Husbandry, Agricultural College of Sweden n 29, 1975.
- TUVESSON M.Effect of water supply on growth and development in some forage crops under different environmental conditions.Reports and dissertations from the Department of Plant Husbandry, Agricultural College of Sweden, n 22, 1974 (in Swedish with an English summary).
- WALLGREN B.Effects of aminotriazole on Agropyron reens (L.) Beauv.Reports and dissertations from the Department of Plant Husbandry, Agricultural College of Sweden n 28 , 1975.

3.Environmental effects on competition :

- HALLGREN E.Development and competition in stands of ley plants and weeds.3.Influence of temperature.Swedish Journal of Agricultural Research 6, 263-268 , 1976.
- HAKANSSON S.Experimental demonstration of the importance of light and temperature for the growth and competitive ability of different weed species.Demonstration experiments for students of plant husbandry (unpublished).

4.Environmental influence on effects of herbicides and growth regulators:

- CARLSSON H. & OLOTTSON B.Influence of temperature and light on the haulm killing effect of Reglone (unpublished).
- HAKANSSON S.The phytotoxic effect of TCA at different temperatures.Annals of the Agricultural College of Sweden 36, 361-379, 1970.
- HAKANSSON S.Influence of temperature on the effect of linuron as soil or leaf herbicide.14th Swedish Weed Control Conference, Agricultural College of Sweden, 1973 (in Swedish).
- HAKANSSON S.Temperature influence on the effect of soil applied dalapon on Agropyron repens (L.) Beauv.Proceedings European Weed Research Society Symposium on Status and Control of Grassweeds in Europe, Paris, 1975, 139-145.
- HAKANSSON S. & SVENSSON A.Influence of temperature on the effects of 2, 3, 6-TBA and ioxynil.14th Swedish Weed Control Conference Agricultural College of Sweden 1973 in Swedish .

WUNSCHE U. Influence of growth retarding substances on cereals. I. Influence of CCC, DMC and CEPA on components of yield in greenhouse and growth chamber experiments with barley and spring wheat. Zeitschrift für Acker- und Pflanzenbau, 136, 331-341, 1972.

WUNSCHE U. Influence of growth retarding substances on cereals. II. Effects of temperature and light intensity on the influence of CCC on tillering of barley and spring wheat. Zeitschrift für Acker- und Pflanzenbau 138, 129-136, 1973.

WUNSCHE U. Influence of day length and light intensity on the growth retarding effect of CCC on wheat (unpublished).

Editor's Note. Following publishing work in 1976 and 1977, with Department catalog numbers and year of publication:

- | | | |
|-----------|------|--|
| °
N 41 | 1976 | Aberg. E. (ed): Vaxtöljder och markförhållanden. Vaxtödlingsdagen 1976. 10 kr. |
| °
N 42 | 1976 | Kvist, K.A. Lagring av potatis. Litteraturoversikt 9 kr. |
| °
N 43 | 1976 | Nyström S. Resultat från några långvariga vaxtöljdsförsök Skåne 6 kr. |
| °
N 44 | 1976 | Kornher A. Sockerbetor och ettårig vall i sydsvenska vaxtöljder. Resultat från en försöksserie. 2 kr. |
| °
N 45 | 1976 | Jonsson N. Vallgräsens näringsreserver-studium av faktorer som inverkar på upplagring och utnyttjande. (Diss.)
Summary: Reserve substances in forage grasses-studies of factors influencing accumulation and utilization of reserves. 13 kr. |
| °
N 46 | 1976 | Bodin B. Blötkökning hos matpotatis (Diss.)
Summary: Softening of table potatoes 9 kr. |
| °
N 47 | 1976 | Albertsson C.E. Bakning med råg (Diss.)
Zusammengassung: Die Verwendung von Roggen beim Backen 11 kr. |
| °
N 48 | 1976 | Dobrovich L. Influence of chlormequat (CCC) on barley (Diss) 9 kr. |
| °
N 49 | 1976 | Svensson C. Betets kvantitet och kvalitet vid olika betesintensiteter. Försök 1969-1972 med ungarna vid Kasby Uppsala län (Diss). Summary: Quantity and quality of pasture production at different grazing intensities. Experiments 1969-1972 with steers at Kasby, Uppsala county 8 kr. |
| °
N 50 | 1976 | Roland J. Skördeteknik i slåttervall - en litteratur- översikt 17 kr. |
| N°51 | 1976 | Ingvar B. Utaadesproduktionen för den svenska potatisodlingen 15 kr. |
| °
N 52 | 1976 | Stecko V. Herbicidens persistens i jord efter olika jordbearbetning. Undersökningar med simazin, linuron och TCA.
Summary: Persistence of herbicides in soil after different types of soil tillage. Experiments with simazine, linuron and TCA 6 kr. |
| °
N 53 | 1976 | Avholm K. & Wallgren B. Renkavle <u>Alopecurus myosuroides</u> liuds. och akervan, <u>Apera spica venti</u> L.-uppträdan och biologi 5 kr. |
| °
N 54 | 1976 | Aberg E. Framtida uppgifter för vaxtödlingsdagen 2 kr. |

- [°]_N 55 1976 Ohlsson I.Kvgve till varraps
Summary:Nitrogen fertilization to spring rape 5 kr.
- [°]_N 56 1977 Stecko V.Vertikal transport av triklorgttiksyra (TCA) i jord'
Summary; Vertical movement of trichloroacetic acid (TCA) in the soil
4 kr.
- [°]_N 57 1977 Carlsson H. Bredspridning och radmyllning av kvgvegOdsel till potatis.
Olika tidpunkter och olika markfuktighet. 7 kr
- [°]_N 58 1977 Nilsson H.Herbiciders persistens i jord.UndersOkningar 1971-1975
(Diss)
Summary:Persistence of herbicides in soil.Investigations in 1971-1975
35 kr.
- [°]_N 59 1977 Carlsson H.FOrsOk med kluvet utsgde av potatis.2 kr.
- [°]_N 60 1977 Larsson R.red (ed): Institutionen fOr vgxtodling.Organisation och
aktiviteter
Department of Plant Husbandry-Organization and activities .Utan
kostnad.
- [°]_N 61 1977 Korhner A. Kvgve till klOver grgsvall med olika typer av rOdkliiver
6 kr.
- [°]_N 62 1977 Korhner A.Vallanlaggningsfgrak. Olika insaningsgrsDor med varierande
kvgveedsling 4 kr.
- [°]_N 63 1977 Korhner A.VallanliggningsfOrsa .KvgvegUsling till nyanlagd rOdklg-
ver-grgsvall 5 kr.
- [°]_N 64 1977 Korhner A. & Rodskjer N.Bestgmningar av den fotosyntetiskt verksamma
stralningen i bestand av havre och korn.
Summary:Determination of the photosynthetically active radiation in
stands of oats and barley.5 kr.

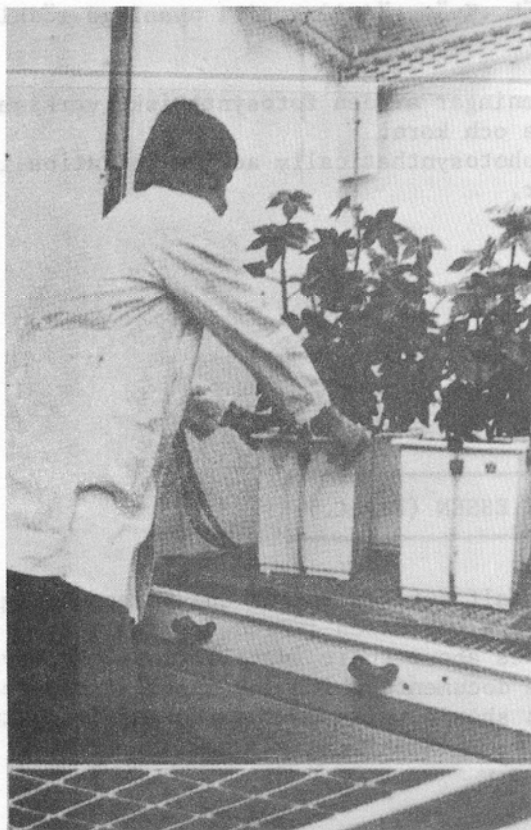
VII. LIB LABORATORY AT ESSEN (F.R.G.)

Editorial Note- Dr.H.VAN HAUT of the Landesanstalt fur Immissions and Bodennutzungsschutz (LIB) of the Nordtchein - Westfalen regions (43 Essen 1 Bredeney- Wallneyer Str.6, Germany, FRG) sent us a series of documents about their installations. We have taken information concerning plants from these documents which may interest our readers.Those desiring to obtain more information should write to the address indicated above.



Petites serres de fumigation permettant l'étude des effets de quantités précises de polluants sur les plantes.

Small greenhouses for knowledge of the effects of exactly controlled quantities of pollutants on the plants.



Chambre climatisée. Mise en place des plantes pour étude des polluants individuellement ou en combinaisons, afin d'établir les critères de qualité de l'air.

Climatic chamber. Into the chambers plants are exposed to single pollutants and their combinations for the establishment of air quality criteria.

Establishment

By the beginning of the fifties, the consequences of industrialisation came into the range of scientific studies, especially in Northrhine Westphalia. Concurrent with these efforts, the government of Northrhine-Westphalia secured comprehensive scientific consultation to support its own activities by establishing the LIB on December 1, 1963. Therefore, it is not surprising that measurable success was achieved in Northrhine Westphalia especially in the field of air pollution control.

Establishment of the LIB essentially was finished in 1968. Within the buildings of the institute, an area of 13000 square meters is at disposal for office rooms, workshops, and laboratories. The technical and scientific problems of air pollution control and soil conservation are studied in 92 modern well equipped laboratories, a technical laboratory of 700 square meters greenhouses, and automatized exposure chambers. Specially equipped rooms have been established to study problems caused by noise and vibration. At present, about 45 million DM have been invested by buildings and scientific equipment.

Scope of Activities

The task of the State Center is to carry out research and development in the fields of air pollution control, protection against noise and vibration, and preservation of soil for agricultural and forest use.

As a scientific and technical institution of the state of Northrhine-Westphalia, the LIB has no executive power. It only becomes active in the public interest upon specific request. Therefore, claims of influences upon the environment should not be addressed to the state center but to the appropriate controlling authorities which, on their part, may consult the state center.

Results of research and development are published in the Periodical Report of the LIB or other pertinent scientific periodicals. The training program, with its interdisciplinary courses also includes problems of environmental protection which are not necessarily treated at the Institute. Useful application of experiences and knowledge gained at the LIB is found in exchange of scientific experiences with national and international experts.

Organizing Structure

The LIB belongs to the portfolio of the minister of labour, health, and social affairs of Northrhine Westphalia, whereas the minister of agriculture, food and forests participates in the technical supervision as far as soil conservation and protection of the landscape are concerned.

The Institute is led by a president and is divided into six divisions with technically adjusted sections. A scientific council of 52 scientists has been formed to promote exchange of scientific knowledge as well as to give advice to the president and the division leaders. At regular time intervals, the aims of work are discussed with the scientific council.

45 of the 370 employees have a scientific education and 65 are educated as engineers. Scientists of all important branches are represented (biologists, soil scientists, chemists, mathematicians, meteorologists, measuring and regulating technicians, physicists, technologists, and others).

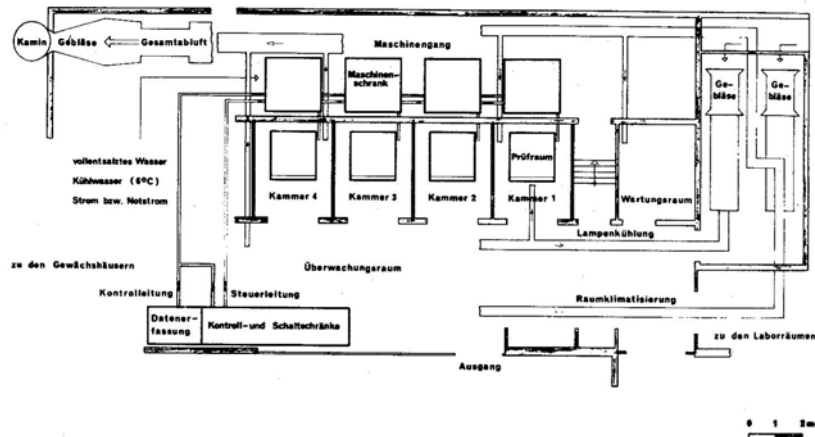
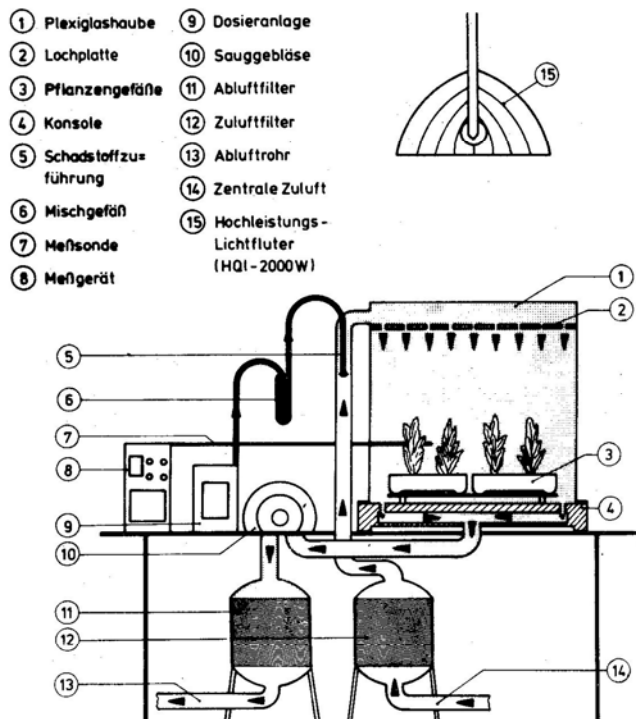


Abb. 1: Grundriss, Aufstellungsplan und Versorgung der Klimakammern

Repartition of climatized room and principle of pollutants distribution.



Scheme of intermittent distribution unit of air pollutants, and their control.

Abb. 3: Schematische Darstellung einer Begasungseinheit aus dem Kurzzeitbegasungssystem

The 6 divisions are:

Division 1. Administration and general facilities
Division 2. Surveillance of air quality
Division 3. Abatement of air pollution
Division 4. Effects of air pollution
Division 5. Soil conservation
Division 6. Prevention of Noise and vibration

Surveillance of Air Quality

The LIB makes use of an integrated monitoring system to control air quality in the densely populated and heavily industrialized areas along the Rhine and the Ruhr rivers. The system consists of five measuring nets which are projected on each other. The sampling sites of the different nets have distances from each other of 1, 5, 7, 10 and 14 kilometers respectively. Measuring net 1 is based on topographic maps which have coordinates a distance of 1 kilometer from each other. Their intersections mark the location of the sampling sites. From measuring net to measuring net the sampling frequency increases with growing distances of sampling sites. Since there is a correlation between survey data related in time and space, the information gained by one measuring net can be transferred to another e.g. by means of regression analysis. By introduction of the integrated monitoring system, the expenditure for air quality surveillance could be reduced considerably.

The integrated monitoring system is used for surveying various pollutants in large areas. With about 6 000 square kilometers, the LIB has established the largest continuous survey area in the world. Dustfall and sulfur dioxide concentrations have been determined at more than 4 000 sampling sites beginning in 1963 and 1964 respectively. The surveillance was extended to the determination of hydrocarbons, hydrogen fluoride and respirable particulate matter in 1970. The results of these air pollution inventories are summarized yearly in maps, which show the different impacts for area units of one square kilometer. These assist the controlling and planning authorities as a decisive aid in making decisions in licensing and zoning proceedings. They indicate the effectiveness of introduced preventive measures against air pollution.

Within the scope of surveillance programs with special aims, hydrogen sulphide, hydrogen phosphide, lead, zinc, polycyclic hydrocarbons and other compounds are determined.

Smog Warning Service

By 1964, the state government had established a smog warning service and a smog alarm plan, issued to protect the people against exceptionally high accumulation of pollutants in the air during stagnating weather conditions. The alarm plan provides limiting of traffic and a change in fuel in industry if certain pollution levels are exceeded. As indicator for the degree of pollution, sulfur dioxide concentrations are recorded continuously at 13 measuring stations. Survey data are transferred directly to the computer of the LIB by telephone lines. The completely automatized air surveillance system allows a constant survey of the air pollution situation in the Rhine/Ruhr area.

Effects of Air Pollutants

Odour nuisances, plant damage, strong corrosions and decays are the first perceptible signs and sensitive determinants of a polluted atmosphere.

Plants are easy to handle test objects to study harmful effects. To many pollutants they show a more sensitive reaction than man. Therefore, the effects on agricultural and forest plants caused by sulfur dioxide, nitrogen oxides, hydrogen fluoride, hydrogen chloride, heavy metals, organic compounds and other pollutants are studied in laboratories, climatic exposure chambers and field experiments. The results of these experiments yield an estimate of the risks for man and his environment.

Suitable plant species, such as lichens and grasses, are exposed to the polluted atmosphere under standardized conditions as biological measuring procedures. The accumulated amount of a pollutant, e.g. lead, or the damaged percentage of leaf area are among many measures of damage.

Materials, which have been exposed to a polluted atmosphere, often show a strong decay. This is especially serious on irreparable works of art. In cooperation with the state curators, protecting and conserving media are tested by the LIB. These methods are developed to limit further decay.

At the trial station for fumigation of plants under field-like conditions (fig.1), exactly controlled quantities of pollutants are passed into small greenhouses in order to gain knowledge of the effects of these pollutants on plants.

Under controlled conditions (fig.2), plants which are raised in greenhouses are exposed to single pollutants and their combinations in climatic chambers for the establishment of air quality criteria.

Soil Conservation

The ecologically balanced system, soil-vegetation is increasingly influenced by the consequences of water engineering; excavation, and mining activities. Withdrawing of water for drinking and industrial purposes, draining, deep reaching hydraulic activities on running and stagnant waters, damming up of surface waters, lead to far reaching increases and decreases of the ground water table. The LIB carries out many studies to evaluate the consequences of such interferences of the water regimen of the soil. The results of these investigations form the basis for the conservation and reclamation of a nearly natural landscape.

Winning of minerals resources leads to interferences with the structure of the landscape by losses in mass and their consequences. The LIB has the task to prepare the basis and to establish standards for the reclamation of excavation and strip mining areas. Subsequent use in conformity with the site allow the reincorporation of affected areas into the landscape. In this connection field experiments are carried out to clarify the question of what precautions must be taken in the development of transposed raw soils poor in humus and nutrient content to arable land with a fertility as high and persistent as possible.

Soil, ground and surface water are polluted, to an increasing extent, by mineral oils, garbage, residues of pesticides and nutrients. Basic problems arising from this are studied in laboratories and at experimental stations (lysimeter, ground water experimental field).

General Facilities

There are a number of facilities available for the use of all technical divisions. For the treatment of the extensive measuring data, especially from the air pollution surveillance programs, a computing center is available. It also can be used for process control with experimental studies.

New developments of analytical instrumentation, monitoring and experimental equipment can be built in machine, fine mechanical or electronic workshops.

The state of the literature collection in the library is being constantly improved and broadened. The reference library has its emphasis on environmental matters, and there are more than 200 technical journals at hand. A complete scientific and technical documentation of the widespread publications on environmental science is being established.

Knowledge, in the fields of air pollution research and soil conservation, is disseminated in an extensive educational programme. The programme is divided into three levels (basic, intermediate, and special courses), and is directed mainly at those members of local and governmental authorities and institutions concerned with air pollution and soil conservation problems but is also open to all interested parties. An informative brochure will be sent on request.

Some results

From : "Staub" Band 21 (1961) n°2 Seite 52/56 by dr.H.van HAUT.

The evaluation of tolerance limits for sulphur dioxide requires knowledge of the quantitative relationships between the immission and the effect. On the basis of gas exposure experiments in "climatic chambers" it has been possible to follow the relationship between plant reaction and the individual influencing factors. It has been possible to obtain particular information about the relationship between the harmful effect and the concentration of the sulphur dioxide and the length of time for which it acts, and also about the significance of the stages of development of the reaction of plants to SO₂ influences. Important indications have been obtained from this for the evaluation of tolerance limits, in the open air experiments.

Dr.H.van HAUT (Staub Reinhalt, Luft 35 (1975) n°5 may 187-193

In short time tests the relative phytotoxicity of nitric oxide was determined on 60 types of plants by comparing it with that of sulphur dioxide as the standard component. For the limitation of NO₂ immissions, in order to protect the vegetation an average value of 0.35 mg NO₂/m³ of air is obtained for the vegetation half-year: the average value obtained during 30 minutes is 0.80 mg NO₂/m³ of air. For assessing the NO, immissions which are still permissible it is, however, necessary to consider, in addition to the individual effects, the combined effects of NO, with other pollutants, and also the indirect effects of nitric oxide by phytochemical secondary products.

Dr.R.von ZAHN (Staub Reinhalt. Luft 35 (1975) n°5 may 194-197.

The tolerance limits of plants to NO, lie 2 to 8 times as high as those to SO₂. Gassing for 2 to 3 hours with a concentration of about 5 mg NO/m³ is tolerated even by sensitive plants. Intermittent exposure to NO₂ is less injurious than continuous

gassing. Gassing for a period of weeks with 2 to 4 mg NO₂/m³ resulted in reductions in yield as high as 37 %. Visible damage, such as necrosis or chlorosis, may be absent. The safe limit for the most sensitive plants is 0.5 to 0.8 mg NO, /m³. When subjected to exposure for short periods, plants are more sensitive at night than during the day. Good nourishment increases the resistance of plants to NO₂ exposure.

Dr.R.GUDERIAN. Air Pollution. Phytotoxicity of acidic gases and its Significance in Air Pollution Control. 1977. Springer Verlag Berlin 150 pages,

Contents: Materials and Methods. Experimental Analysis of the Effects of Gaseous Air Pollutants. Comparisons of the Phytotoxic Characteristics of Sulphur Dioxide, Hydrogen Fluoride, and Hydrogen Chloride. Discussion of the Suitability of Plant Responses as a Basis for Air Pollution Control Measures.

VIII. THE PLANT GNOTOBIOLOGY LABORATORY: DESCRIPTION, PROCEDURES AND USES

Nina HOPKINS and Maynard HALE

Department of Plant Pathology and Physiology, Virginia Polytechnic
Institute and State University-Blacksburg, Virginia 24061 USA.

Abstract. A technology has developed in the last few years which enables investigators to culture plants to maturity axenically in quantities sufficient for replicated experiments and biochemical assay. Plants are cultured in isolator chambers placed in growth rooms. Techniques for obtaining and maintaining aseptic plants for studies of biochemical (allelopathic) interactions between plants and between plants and microorganisms have been developed and specific factors which affect exudations of biochemicals that may be substrates in the rhizosphere or chemical messengers have been identified.

Introduction. A technology is developed in the last few years which enables investigators to culture plants to maturity axenically in quantities sufficient for replicated experiments or for biochemical assay. The technology known as gnotobiotics represents one more step in the refinement of techniques to culture plants under controlled environments.

Plants are cultured in chambers (isolators) which meet the following criteria (HALE et al. 1973); (a) plants can be grown to maturity within them, (b) are easy to maintain, (c) have a short turn over time between experiments, (d) have room for replication of experimental treatments, (e) are housed in a room where light and temperature can be controlled and/or measured, (f) facilitate use of several kinds of rooting media, (g) provide for growth of two or more different kinds of plants in the same chamber for studies of interactions, (h) facilitate manipulations of microorganisms in association with plants, (i) provide for transfer of experimental materials into and out of the chamber at any-time during an experiment.

In addition to growth rooms for placement of isolators, a gnotobiology laboratory needs ancillary facilities for preparing and sterilizing equipment and seeds; for making nutrient media for plants and sterility tests of the chambers; for harvesting and preparing plant materials for analysis, and for chemical analyses of plant materials.

History and Description of a Plant Gnotobiotic Facility

The plant gnotobiotic facility in the Department of Plant Pathology and Physiology at Virginia Polytechnic Institute and State University was developed to meet the needs of researchers who were interested in describing and measuring the biochemicals interacting between plants and between plants and microorganisms. For example, the colonization of roots by soil borne organisms is a complex series of reactions involving chemical messengers and organic substrates in the rhizosphere. If an understanding of the colonization process is to be gained, the system needs to be simplified so that sources of the biochemicals can be identified and their effects on the ecology of the rhizosphere established. Similarly, germination of some weed species and of parasitic plants such as dodder (*Cuscutis* sp.) and orabanche are affected by biochemicals released by host plants. It is necessary to culture plants in the absence of microorganisms to obtain unaltered the chemical messengers (exudates) or substrates or to culture them in the presence of known organisms, be they microbial pathogens, symbionts, colonizers or other plants, so that the biochemicals that are interacting in an ecosystem can be identified.

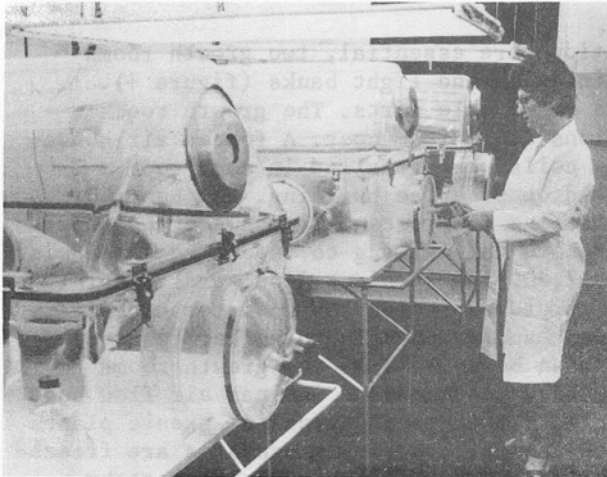


Fig.1. Isolateurs en plexiglas sur supports en place dans une chambre de croissance avec panneau de tubes fluorescents au dessus de chaque isolateur.

Fig.1. Plexiglas isolators on carts in place in growth room with fluorescent light banks above each isolator.

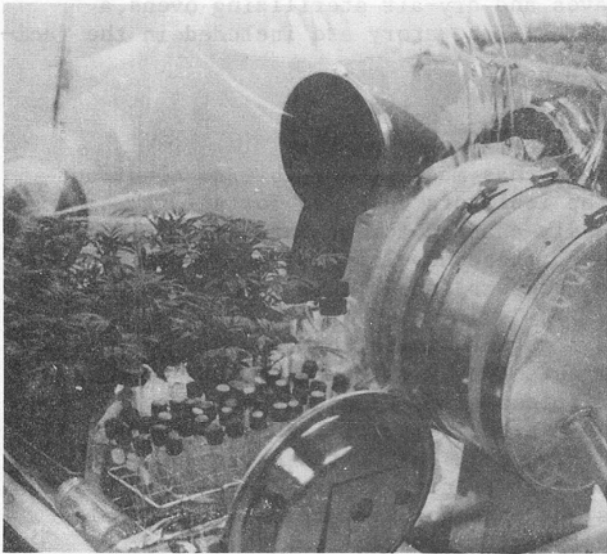


Fig.2. Isolateur en film plastique (sac) avec tubes de contrôle de la stérilité, plantes et équipement pour une expérience à l'intérieur.

Fig.2. Soft plastic isolator (bag) with sterility check culture tubes, plants and equipment for an experiment inside.

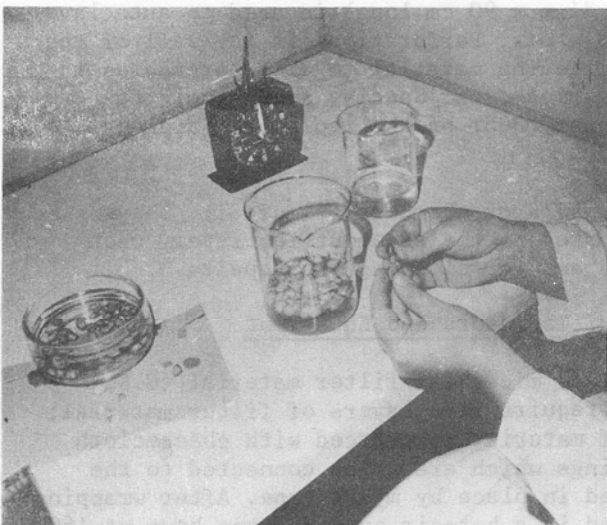


Fig.3. Elimination de l'enveloppe des graines d'arachides et stérilisation des graines dans une solution NaOCl à 50°C pendant 5 minutes c'est la technique utilisée pour obtenir des plantes axéniques d'arachide qui seront placées dans les chambres isolateurs après test de stérilité.

Fig.3. Removal of the testa from peanut seeds and sterilization of the seeds in NaOCl solution at 50 C for 5 min is technique used to obtain axenic peanut seeds which will be placed into an isolator chamber after testing for sterility.

Since controlled environmental conditions are essential, two growth rooms were constructed with appropriate air conditioning and light banks (figure 1). Each room has space for 6 isolator chambers on movable carts. The growth rooms were designed to furnish controlled conditions at minimum cost. A forced air, household electric furnace with air conditioning coils was installed in each room, and the refrigerating condensers were mounted outside the building. Six banks of lights each consisting of 16 cool white slim line fluorescent lamps were suspended from the ceiling with the ballasts mounted above the ceiling to reduce heat load in the rooms. Light intensity is approximately 7,500 lux at plant level and temperature control range is from 20 to 30 C + 5 C. Temperatures inside the isolator chambers are usually 3 to 5 degrees higher than ambient and do not fluctuate more than one degree from the mean. The isolator chambers can be moved from the growth rooms to an adjacent laboratory for harvesting plants, and cleaning. A laminar air flow hood with 6 feet of bench space is used for aseptic transfers and treating axenic plants or plant parts. Plant samples and nutrient solutions containing exudates are freeze-dried and stored for later analysis by thin layer and gas-liquid chromatography.

A preparation laboratory with autoclaves and dry-air sterilizing ovens, a small wet chemistry laboratory and an analytical laboratory are included in the facility.

Equipment Used in Plant Gnotobiology

The advent of plastic films and plexiglas has made it possible to construct chambers of assorted sizes and shapes but the isolators designed for animal research and which are commercially available are easily adapted for research with plants (figures 1 and 2). REUZER, (1962) has reviewed these developments and TREXLER (1959) described the use of plastics for germ free chambers and walk in rooms.

The key to success in designing and using gnotobiotic chambers in the air filtering system which must exclude microorganisms over extended periods of time while allowing air to enter and exit in sufficient quantities and purity to sustain plant growth. Filters consist of fiber glass material several layers thick, which prevents microorganisms from growing through it during the course of an experiment, and metal supports. Attached to the isolator inlet filters is a small blower that runs continuously and maintains a constant internal air pressure which helps prevent contamination and also supports the flexible plastic isolators.

A stainless steel cylinder, (30.5 cm diam x 90 cm long) is used to autoclave equipment and materials used inside the isolators. Perforations in the wall of the cylinder are covered with the fiberglass filtering material to allow pressures to equalize during the autoclaving and cooling processes. Special stands hold the autoclaved cylinders at the height of the entry door on the isolators (see next section)

Specially constructed carts hold the isolator chambers (figure 1). They can be moved about in the growth rooms or moved to the adjacent laboratory when necessary for harvesting or treating plants and for cleaning and repairs.

Preparation of Isolators and Equipment

Two types of filters utilize fiber glass microbial filter material (G.F. Supply, Palatine, IL). Disc shaped filters require five layers of filter material; cylindrical filters require three rounds of material reinforced with cheesecloth to prevent tearing. The filter outlet openings which are to be connected to the isolator are covered with mylar film secured in place by mylar tape. After wrapping in aluminum foil, the filters are sterilized in a hot-air oven for one hour at 160 C and then attached to isolators.

A plastic floor mat, forceps, tongs and scissors may be placed in the isolator before it is sterilized. For sterilization, a stainless steel sprayer operated by compressed air at 12 lbs psi is used to spray the inside of the chamber with peracetic acid (2 to 7 percent v/v) containing two drops of a surfactant, (Tween 20) to each 100 ml of peracetic acid (FMC Corporation, Buffalo, N.Y.) solution. All surfaces inside the isolator are thoroughly wetted by the contact biocide and particular care is exercised in spraying around all openings, gaskets, gloves, mats and tools.

The sprayer is removed and the outer door cover put in place. After standing overnight, the mylar film on the air filters is broken and the attached blower started. Peracetic acid remaining in the chamber is vented to the outside of the building over a period of five to seven days before plant materials are introduced into the isolator.

Equipment such as plant containers, tubing, cotton swabs for sterility checks, and bottles of nutrient solution or chemical solutions for plant treatments is placed in a stainless steel cylinder and the ends of the cylinder sealed with mylar film held in place by masking tape. The cylinders are usually autoclaved for 3 hours at 121 C and 15 lbs psi. To dry the cylinder after the sterilization period, the autoclave door is opened 2 to 3 cm while steam pressure is maintained in the jacket of the autoclave. The length of the drying time varies from 3 to 12 hours and depends on the amount of material in the cylinder and its moisture content.

The cylinder is placed on a height adjustable stand and is attached to the entry port of an isolator chamber by a plastic sleeve held in place by adjustable clamps at each end (figure 2). The inside of the sleeve and entry port are then sprayed with peracetic acid the spray port stoppered.

After 24 hours or more, the inner cover of the entry port is removed, the mylar seal on the end of the cylinder broken and the equipment taken into the isolator. After this is done, the inner entry port cover is then replaced, the entry port sprayed and the cover spray port stoppered.

Making Sterility Tests

Most contaminations have proved to be either bacterial or fungal and tests for viruses and mycoplasmas are not routinely performed. The sterility testing media are selected to detect aerobic and anaerobic bacteria as well as fungi and are easily prepared from commercial dehydrate materials. A common set of media includes potato dextrose agar, SABOURAUD dextrose agar, thiklycollate agar, brain heart infusion agar, nutrient broth, and trypticase soy agar. The isolator floor, walls, ceiling, glove ports, filter openings, entry port and cover, containers, and tools are swabbed individually with damp cotton. The swabs are removed from the isolator, placed aseptically in tubes of the media and incubated for up to 10 days. If growth shows in only a few tubes, the test is repeated to insure that the contamination did not come in the transfer of the swabs to the media. Chambers and plants are only as sterile or axenic as the testing media used indicate them to be.

Preparation of Nutrient Solutions and Water

An internal and an external system have been used to transport nutrient solution and water into the isolators. For the internal system, 16 oz prescription bottles are filled 3/4 full with nutrient solution (Hoagland and Arnon, 1950) or distilled water. Mylar film is placed over the mouth of the bottles and the caps screwed on tightly and then blacked off 1/2 turn. After autoclaving in a sterilizing cylinder, the bottles are moved into the isolator in the usual manner. The bottles accumulate and occupy valuable plant space and the frequent opening of the isolator port increases chances of contamination. For these reasons, an external system was devised.

For the external system, bulk head unions are permanently installed in the end wall so that connecting rubber tubing can be attached inside and outside the isolator. Reservoirs of nutrient solution and of water are carefully autoclaved, cooled and aseptically connected to the rubber tubing outside the isolator and to a sterile cotton or fiber glass air filter. Compressed air from an oil less air compressor is connected to the filter and solution or water as needed is forced by air pressure into the isolator where they are used to water plants or replace the nutrient solution. By using a vacuum on the outside, solutions may be removed also. All connections are wired or clamped to prevent accidental disconnections.

To Obtain Axenic Seedlings

A variety of methods are needed to obtain axenic seedlings. The method selected depends upon the nature of the plant material and the microorganism with which it is associated.

Peanuts (Arachis hypogea)

The method used for obtaining axenic plants from peanut embryos is as follows. The testa is loosened by soaking in warm water and then removed (figure 3). The cotyledons are carefully cut from the embryo and the embryos allowed to dry over night after which time they are sterilized with 20% commercial chlorinated bleach (NaOCl) at 50 C for 5 min. (bleach: H₂O = 20:80+2 drops of a surfactant such as Tween 20). The embryos are aseptically transferred to previously prepared vials

containing nutrient solution solidified with SABOURAUDS dextrose agar. After ten days, the vials containing sterile, germinated embryos are placed into the entry port of an isolator. The floor of the entry port is sprayed with peracetic acid immediately before introducing the vials and then the vials themselves are sprayed. The entry port door is put in place and the entry port sprayed, and stoppered. After 1 hour or more, the vials are transferred into the isolator and the seedlings planted 48 hours later.

If greenhouse grown fruits are available, they usually do not have an internal microflora and the cotyledons and embryo can be surface sterilized intact.

Tobacco

To obtain axenic tobacco seed, the following procedure is used. Harvest seed pods before they are fully ripened. After disinfecting the pods in NaOCl: H₂O solution (20:80) for one minute, place the pods in sterile test tubes and store them in a refrigerator. When the time arrives to use the seeds, place two pods in a small bottle filled with NaOCl solution and crush the pods with a pair of sterile forceps. Cap the bottle and place it in the entry port of an isolator and spray the entry port. After approximately 6 hours, transfer the bottle containing tobacco seeds into the isolator and pour the seed directly into previously sterilized vermiculite soaked with nutrient solution.

An alternative method is to remove the seeds from the pods, disinfect them with NaOCl solution and transfer them to tubes of sterile medium.

Loblolly Pine

Pine seeds need to be scarified for a prescribed period before surface sterilization. To disinfect the seeds, proceed as follows. Soak the seeds in a solution of detergent for approximately five minutes. Rinse in tap water and repeat the detergent solution wash followed by a second rinsing. Allow to drain, and place the seed in 1% H₂O₂ solution for 24 hours at 5 C. Pour off the peroxide solution and repeat the peroxide treatment. Cover the seeds with 30% H₂O₂ and shake for

30 min on a wrist action shaker. Aseptically transfer the seeds to 1% corn meal agar in vials and allow the seeds to germinate before moving them into an isolator.

Corn

The microfloral population of corn caryopses is difficult to kill but the following procedure works most of the time. Place the caryopses in 30% H₂O₂ and shake on a wrist action shaker for ten minutes. Aseptically transfer the caryopses to vials containing a medium made up of one quarter strength Hoagland's nutrient solution solidified with SABOURAUD dextrose agar.

Tomatoes

Tomato seeds are rinsed thoroughly in concentrated hydrochloric acid to remove seed coat hairs. Seeds are washed thoroughly in running tap water to remove all to the hydrochloric acid (approximately 10 min). The seeds are then sterilized with NaOCl for ten minutes after which time they are aseptically transferred to corn meal agar in test tubes.

Marigolds

Marigolds have been found to be one of the easier plants to culture gnotobiotically. Soak the seeds in concentrated NaOCl for ten minutes and then aseptically transfer to 1% corn meal agar or 1/4 strength Hoagland's nutrient solution solidified with SABOURAUD dextrose agar.

Soybeans

Some varieties and some seed lots of soybeans contain an internal microflora that's difficult to remove. Assuming that surface sterilization or disinfection will be sufficient, seeds are soaked in water to soften the seed coat which is then removed. Allow the seed to dry and then treat in the usual manner with warm NaOCl solution. Aseptically transfer the surface sterilized seeds to tubes containing SABOURAUD dextrose agar medium.

Root Exudation

Loss or release of organic compounds from plant roots is affected by a variety of environmental and physiological factors (HALE et al. 1977). The effects of various factors on exudation can be studied best under axenic conditions where exudates can be collected without alteration by microorganisms. If a colonized root system is being studied, the effects of known microorganisms on exudation can be studied under gnotobiotic conditions.

Exudates are involved in such processes as root colonization, nutrition of rhizosphere populations of microorganisms, and interactions in plant nutrition. They also affect fungal spore germination and weed seed germination. Alteration of exudation patterns by foliar applications of **plant** hormones, pesticides, and mineral nutrients can lead to control of rhizosphere populations of microorganisms and plant propagules in allelopathic reactions.

Collection and Preparation of Exudates

Under hydroponic conditions, the nutrient solution bathing the roots is collected periodically, filtered through a millipore filter, and stored at 5 C until such time as the water can be removed by ether, flash evaporation or freeze drying. Dried samples are stored in a desiccator until they can be analyzed.

If an inert, solid rooting medium such as sand or weblite is used, exudates can be leached out with a flush of nutrient solution and the leachates dried and stored.

Analysis of Exudates

Analytical procedures vary with the organic compound group being analyzed, Most commonly, sugars and amino acids have **been measured. More recently, sterols** and fatty acids have been determined as appropriate volatile derivatives by gas **chromatography. Frequently, preliminary** separations are made using thin layer preparative chromatography and the bands eluted from the stationary phase and appropriate derivatives quantitatively measured by gas chromatography.

Literature Cited

- HALE M.G., L.D.MOORE and G.J.GRIFFIN.1977. Root **exudates and** exudation. In: Y.DOMMERGDES and S.KRUPA (Eds) Interactions between soil organisms and plants. Elsevier, Ansterdam.
- HALE M.G., D.L. LINDSEY and K.M.HAMEED.1973. Gnotobiotic culture of plants and related research. Bot.Rev.39, 261-273.
- HOAGLAND D.R. and D.I.ARNON.1950. The water culture method for growing plants without soil. Calif.Agric.Expt.Sta.Circ.347.
- REUZER H.W.1962. Axenic techniques in the determination of root functions and the interrelationship of microorganisms and plant roots. Soil Sci.93, 56-61.
- TREXLER, P.C.1959. The use of plastics in the design of isolator systems. Ann.N.Y. Acad.Sci.78, 29-36.

IX. CONTROLLED ENVIRONMENT FACILITIES AND THEIR USE AT THE GLASSHOUSE CROPS RESEARCH INSTITUTE, Littlehampton, U.K.
--

B. ACOCK and R.G.HURD

Glasshouse Crops Research Institute.Worthing Road-Rustington-
Littlehampton Sussex U.K.

Introduction

There are no phytotrons in the U.K. and hence no phytotronists. However, there are a large number of plant growth cabinets each capable of controlling plant environment over a wide range of conditions and there are a corresponding number of biologists who have learnt sufficient about engineering to be able to operate these cabinets.

At Glasshouse Crops Research Institute we have about 40 cabinets and rooms operational at present and more in preparation. These vary widely in the number and range of environmental conditions controlled and some of the most sophisticated cabinets, which are used in the Plant Physiology Department, are described below. Both

artificially-lit and daylit cabinets are available: the former for use where complete control over the duration and flux density of the radiation environment is necessary and the latter as a half way stage to glasshouse or field crop trials. Thus, we attempt to relate observations made in cabinets to our experience in the glasshouse and field. Since the daylit cabinets are less common than artificially lit cabinets they are described in more detail.

Artificially lit plant growth cabinets

1. TWO Mark I and four Mark II Saxcil cabinets

These are six of the one hundred or so standard cabinets purchased by the Agricultural Research Council from R.K. Saxton Ltd. The two Marks are essentially similar. They have a floor area of 1.86 m² (20 ft²) and a useful height of approximately 1 m. Their temperature range is claimed to be 5 - 32°C with relative humidity control down to 55% r.h. between 15 and 30°C. Humidity is controlled by cooling all the air at each cycle down to the dew point. Water vapour is supplied in the present cabinets by passing the air over a permanently damp strip of material. Refrigeration is by secondary coolant supplied from remote refrigerate tanks each serving a pair of cabinets. Individually switched warm white fluorescent lamps in two tiers give maximum irradiance of approximately 120 W m² P.A.R. at floor level. The Mark I cabinets leak at 2 air changes per hour with the air vents closed; the Mark II cabinets at 0.25 air changes per hour. CO₂ concentration is monitored and controlled. Air velocity in the cabinets can be varied between 0.06- 0.18 m s⁻¹.

2. Five Air conditioning (North-West) Ltd., cabinets

These cabinets have the *same* plant space as the Saxcil cabinets but at present their range of environments is smaller. They have positive humidity control since all the air is brought to the desired dew point by passing through a spray of chilled water. Their single bank of lamps produces a maximum irradiance of approximately 80 W m⁻² P.A.R. They are housed in a temporary building at present and do not function as accurately or as reliably as the Saxcil cabinets.

Recent research in artificially lit cabinets

1. The effect of irradiance, temperature and CO₂ concentration on the growth of young tomato plants
2. The effect of photoperiod, temperature and irradiance on flower induction and stem growth in chrysanthemum.
3. The influence of apical dominance on the flower induction of laterals in chrysanthemums.
4. The effect of photoperiod, irradiance and temperature on tulip flowering, growth and leaf senescence.
5. The provision of standard plants for translocation and photosynthesis studies.
6. Variations in water culture techniques for growing tomatoes.
7. The induction and prevention of tip burn in lettuce.

Future research in artificially lit cabinets

1. Analysis of tomato leaf growth in relation to the environment.

This includes studies on anatomy, morphology, photosynthesis and translocation, linked to an overall model of leaf growth.

2. Continuing experiments on the effects of photoperiod, light quality and growth regulators on growth and flowering of chrysanthemum.

Artight, daylit plant growth cabinets

Daylit cabinets have the advantage over artificially lit cabinets that plants grown in them experience light of a similar quality to that available in the field and identical to that in glasshouses. However, the varying irradiances makes it difficult to interpret growth analysis data or any other data on crop responses which integrate changes in environmental factors over hours or days. Fortunately the technology is now available for us to measure net CO₂ assimilation by plants in the cabinets over a few minutes and relate this to irradiance over the same period. Using this technology, the former disadvantage becomes an advantage because we can obtain a complete light response curve for photosynthesis during the course of a single (sunny) day. To facilitate these CO₂ flux measurements the daylit cabinets have been constructed as nearly airtight as possible. The prototype daylit cabinet at G C R I consists essentially of sides of 6 mm plate glass and a top of 10 mm armoured glass bedded on "non hardening" mastic in a frame of 29 mm steel angle. The transparent plant space is cubic with sides 2.15 m long. Within the space, 154 mm from the east side is suspended a 6 mm sheet of "Perspex" extending across the whole cabinet, with a 160 mm gap at the top, forming one side of the return air duct. The cabinet has a temperature range of 10 to 30 C and dewpoint control of relative humidity in the range of 80 to 90% r.h. at 10C and 45 to 90% r.h. at 30C. The rate of vertical airflow past the plants is 0.4 m s⁻¹ which is equivalent in this cabinet to one circuit of air every 12 seconds. The lowest leakage rate achieved so far is 0.02 air changes per hour. Further details of the daylit cabinet have been published by ACOCK (1972). A null balance method is used to measure the net canopy photosynthesis of crop stands over intervals of 10 minutes. CO₂ concentration is controlled to within + 0.5% of the desired value. The amounts of CO₂ used in canopy photosynthesis are measured with a linear mass flowmeter accurate to + 10 mg CO₂. The total errors incurred in the measurement of crop photosynthesis are estimated to be of the order of + 30 mg i.e. + 0.75% to + 2.5% over a range of solar irradiance from 100 to 450 W m⁻². For further details see HAND (1973).

Commissioning of three more daylit cabinets is almost complete and these differ from the prototype in having wet bulb control of relative humidity, airflow rate variable up to 0.6 m sec⁻¹ and leakage rates of less than 0.01 air changes per hour.

Recent research in daylit cabinets

During the time the prototype daylit cabinet has been operational, light response curves have been obtained for canopies of tomato, sweet pepper, aubergine, tulip, rose and chrysanthemum. To compare the photosynthetic productivity of C3 and C4 crops under comparable experimental conditions, CO₂ assimilation measurements have also been made on Amaranthus edulis. Models of canopy photosynthesis have been applied to the measurements so as to explore the relationship between environmental factors such as temperature, light and CO₂, canopy structure and the optical and photosynthetic characteristics of individual leaves.

Future research in daylit cabinets

When four cabinets are operational it will be possible to expose crops to various treatments concurrently and to follow their adaptive responses. This will provide the data for developing and testing models of crop growth incorporating previous models of canopy photosynthesis.

References

- ACOCK B.(1972).A prototype, airtight, daylit, controlled environment cabined and the rationale of its specification. In Crop Processes in Controlled Environments, (ed.REES A.R. et al.) pp.91-104.
- HAND D.W.(1973). A null balance method for measuring crop photosynthesis in airtight daylit controlled environment cabinet. Agric.Meteorol.12, 259-270.

x

X. REVISED GUIDELINES FOR REPORTING STUDIES IN CONTROLLED ENVIRONMENT CHAMBERS
--

ASHS Special Committee on Growth Chamber Environments

Editorial Note.This guide list put together by the ASHS Special Committee on Growth Chamber Environment was sent to us by the Committee President. It was published in HORT.SCIENCE vol.12 (4) , August 1977, p.309-310. In the belief that this document may interest readers, we reproduce it in its entirety with preliminary remarks.

x

The following revised guidelines are proposed for reporting research conducted in plant growth chambers.The precise regulation of environmental parameters attained in growth chambers has enabled investigators to study many plant processes with a precision and reproductibility hitherto unavailable. However, the environmental conditions employed in growth chamber studies often are not reported in detail sufficient to allow comparison of the results with similar experiments, or repetition of the studies in other laboratories.

The following guidelines are presented to assist investigators to achieve these objectives. The guidelines also may alert investigators to factors of the environment that could be important in their experiments but which they do not measure at the present time.

The revisions in the guidelines reflect changes in measurement techniques or instrumentation based on research experience and improvements in measuring devices. For example, we recommend reporting visible radiation in units of photon flux density rather than in photometric units.

Each investigator and publication may differ in the manner that experimental parameters are reported, but it is hoped that the following example will be helpful to authors in detailing the environmental conditions reported in research articles. For some, a tabular presentation of critical parameters may be preferred to text.

SAMPLE TEXT

Studies were conducted in a 3 m³ reach-in chamber fitted with a Transpex(i) barrier and having 75% input wattage of 1500-ma cool white fluorescent and 25% input wattage of Lumo(1)100 W 130-V extended service incandescent lighting. The irradiation at the top of the plants was $32.5 \pm 1.0 \text{ nE s}^{-1} \text{ cm}^{-2}$ (400-700 nm) at the beginninL and declined 10% by the end of the experiment. Light was measured with a Berner 1.) meter equipped with a Zeta(1) sensor. The light and dark periods were 16 and 8 hr, respectively, with an abrupt change.

The air temperature over each plant throughout the experiment was $25^{\circ} \pm 1^{\circ} \text{ C}$ in the light and 20 ± 1 in the dark, as sensed with a shielded 24 gauge thermocouple. Soil temperature at the center of the containers was $20^{\circ} \pm 3^{\circ}$, as sensed with a Proban(1) thermistor. The relative humidity was $65 \pm 8\%$ during the day and $73 \pm 5\%$ at night, as measured with an aspirated psychrometer. The air flow up through the plants was 30 m/min at the top of the plant canopy, as measured with a Windo(1) Model 12 hot wire anemometer. Fresh filtered make up air (0.6 m³/min) was provided and CO was monitored with a Manbek(1) infrared gas analyzer and remained above 300 ppm during the light period.

2

Plants were grown in 1 peat: 1 vermiculite: (by vol) in 1-liter white cylindri7 cal polyethylene containers 15 cm in diameter. Plants were placed in the chamber in a randomized block arrangement and irrigated for 5 min each 6 hr with 100 ml of ASHS nutrient solution per container.

(1) Fictitious brand names

GUIDELINES

A. Minimum requirements

Radiation

1. Lamp types and percent input wattage of each type.
2. Light readings. Report values preferably in $\text{nE s}^{-1} \text{ cm}^{-2}$ of mWcm^{-2} for the 400-700 nm wave bandy Give type, spectral sensitivity, make and model of meter used.
3. Location of meter reading in relation to plant canopy.
4. Photoperiod. Indicate if lights are turned on gradually or abruptly; if gradual, indicate program. Indicate length of diurnal cycle if other than 24hr.
5. Lamp barrier. Indicate if present or absent; if present, indicate material used and thickness.

Temperature (T)

1. Air temp with a shielded sensor. Indicate type and location of sensor in relation to the plants, and temp values for day and night.
2. Substrate temperature. Indicate type and location of sensor in the substrate and temp values for day and night.
3. Thermoperiod. Indicate if day-night or other program is abrupt or gradual.

Relative Humidity (IV) or Dewpoint ($^{\circ}\text{C}$)

1. Day and night values. Indicate type and location of sensor.

Carbon dioxide

1. Extent of make-up air (indicate if filtered) .Indicate frequency of complete exchange or rate of addition, giving internal chamber volume.

Air movement

1. Direction of movement (up, down, or horizontal).

2. Air flow rates at top of plant canopy.

Nutrient and media container, substrate, and nutrients

1. Composition, capacity, shape and color of container.

2. Substrate.

3. Nutrient solution used. Indicate macronutrient concentration in meq per liter and micronutrients in mg per liter, frequency and volume of addition, and chelates if used.

4. Method of solution renewal or replacement in liquid culture studies.

5 s= SI abbreviation for seconds,

6 This is reported variously as photosynthetically active radiation (PAR), photosynthetic photon flux density (PPFD) or photosynthetic irradiance (PI). (See Shibles, R.1976 .Terminology pertaining to photosynthesis. Crop.Sci.16, 438-439).

B.Desired additional information

For radiation:

1. Manufacturer and designation of lamps, a) for incandescent and high intensity discharge (HID), indicate rated wattage and operating voltage, b) for fluorescent, indicate loading, 400 ma, 800 ma or 1500 ma.

2. Changes in radiation in space and time.

3. Total radiant energy (mWcm) , indicating instrument and its range of measurement.

4. Gradient in irradiance over the growing area.

5. Spectral energy distribution or spectroradiometric curve.

For temperature:

1. Gradient of air temp over the growing area.

2. Soil thermoperiod in relation to photoperiod

3. Leaf temp, indicating method and location of measurement.

For relative Humidity (%) or dew point (°C):

1. Variations from established level, those during temperature cycling, and changes occurring during the experiment

For Carbon dioxide:

1. Level in the plant area. Variations during light and dark periods; indicate instrument used to monitor and/or control CO₂ levels.

For air Movement

1. Variations in air flow over the growing area, both at the beginning and end of the experiment. Indicate measuring instrument used.

For nutrient and media container, substrate and nutrients

1. Concentration of nutrients at time of solution renewal or replacement, and at the end of the study in liquid culture experiments.

2. Substrate solution pH and pH fluctuations.

3. Source of substrate

4. Tissue analysis.

x x
x

XI. DYNAMIC MODELING OF GLASSHOUSE CLIMATE AND THE
APPLICATION TO GLASSHOUSE CONTROL

G.P.A.BOT, J.J.VAN DIXHOORN and A.J.UDIN(TEN CATE)
Dept. of Physics & Meteorology, Agricultural University,
Wageningen, The Netherlands

ABSTRACT

A system approach to glasshouse modeling and control *is* outlined by presenting two types of dynamical models.

The first type of modeling uses a simple black box model. This is updated by on line estimation and is incorporated in an adaptive computer control system. Results of field trials are included. The second model is more elaborate and based on the heat and water vapour balances in the glasshouse, which are presented in bond graph notation. The application of these models in a hierarchical control system configuration is discussed.

Introduction

Glasshouse cultivation is an important part of Dutch agricultural activity. It is a very intensive way of growing fine vegetables, fruits and flowers in every season. This is accomplished by manipulating the climate in the glasshouse roughly by heating when the temperature is too low and ventilating when it is too high. The main factors determining the cost of glasshouse cultivation are energy, investment and labour. At present the energy cost is only one third of the total cost, because cheap natural gas is used.

However, energy becoming more expensive and scarce, ways to reduce energy cost are to be investigated. Direct methods to prevent losses are applied already on a large scale:

thermal screens, closes at night and open during daytime

exhaust gas condensers, using the condensation heat of the water vapour in the exhaust gases of the natural gas burners; this low temperature heat is used for soil heating.

Another direct approach to reduce energy cost is the use of plant species that give a high production at low temperatures. Search in this direction is already successful

A different approach often called the systems approach is to consider plant production and its associated energy cost a production system that should be controlled to yield an "optimal" performance. Roughly stated three hierarchical levels of control can be distinguished.

I) The control of heating and ventilation to ensure a desired glasshouse climate, independent of the disturbances caused by the weather. Good control of this level will result in energy savings due to the prevention of overheating and of simultaneous heating and ventilation. The usually applied automatic analogue controllers do work on this level.

II) The control of short term conditions to ensure optimal plant growth. Whereas the glasshouse climate itself is controlled on the previous level, the desired values of the climate factors are determined and controlled on this level. The air temperature, for instance, is often automatically increased in accordance with the radiation intensity. Condensation on leaves and flowers should be avoided to prevent diseases and damage. The underlying ideas on this level are partly physiological and partly empirical.

III) The ultimate control level is that of the long term plant development. The short term plant situation should be related to plant development and production. Some empirical rules and much of the growers experience is decisive here. This field is a main challenge for horticulturists.

A basic tool of the systems approach is the mathematical model. In the discussed subject models of the micro climate will be needed on all levels, models of plant growth are needed on level two and three and of plant development on the third level. The ultimate object being improved control, one approach is to incorporate models in a learning control strategy. This implies that the models can be more simple than the conceptual or explanatory models usually applied in research. If the model contains a few unknown parameters an on line parameter estimation technique can be used for updating. As will be shown even a simple black box model, not containing physical but only input-output relations, can give a significant improvement over conventional control.

This paper reports our systems oriented approach to glasshouse climate control. It is performed in cooperation with plant physiological and horticultural groups outside our laboratory. Furthermore close cooperation is established with the Glasshouse Crops Research and Experimental Station at Naaldwijk. The Netherlands, where an extensive digital computer control and data logging system is in operation.

An important motivation for our work is that in this country computer control is not restricted to experimental stations like Naaldwijk. At present over a hundred installations are in use or ordered by commercial growers. These installations are generally minicomputer or microprocessor based. Equipment cost is about \$ **20.000** - and is at the break-even point with a sophisticated analogue controller for about six glasshouses.

The computer provides the grower with attractive data logging and averaging facilities. Algorithms used however, are generally a digital version of the conventional analogue controller. A control philosophy fully exploiting computer capabilities is still lacking. The systems approach, as followed by our group, making use in a stepwise way of simple and increasingly more elaborate models and modern control methods, could lead in this direction.

Our first step, not reported here, has been the construction of a black box simulation model of a glasshouse, its heating system and associated control system. The model was validated with experimental data from the Naaldwijk installation. It was used to improve the conventional control algorithms. The results were used to improve the Naaldwijk computer control and showed a considerable improvement. It became clear, however, that no adjustments for the standard control algorithms could be found that gave satisfactorily control performance under the strongly varying environmental conditions.

So our next step, briefly reported in this paper and more extensively elsewhere (1) has been to develop an adaptive ('selftuning') control algorithm for glasshouse heating. This algorithm continuously tunes the control algorithm depending on the actual situation. To track the actual situation a simple black box model with one adjustable parameter is incorporated in the control system. The adaptive algorithm is presently in operation in all computer control loops at Naaldwijk. Research on this level will be continued on ventilation control.

Another parallel step, also briefly reported in this paper and elsewhere (2) has been the development of a not too complicated simulation model of the glasshouse climate. In contrast to the previously mentioned approach this model is based on the heat and mass balances and on the physical transport phenomena and includes a model of plant behaviour in this respect. The bond graph notation is used to obtain a clear representation and more convenient interactive simulation. The model will be used for accurate simulation and adaptive control.

Glasshouse Climate

Glasshouses are built to improve the environmental factors for plant production. The factors of interest are radiation, temperature, relative humidity, carbon dioxide concentration and wind velocity. First of all these factors are influenced by the reduction of the turbulent exchange. This effect mainly effects the temperature rise in the glasshouse (3).

Another effect is the so called "greenhouse effect": the glass is transparent for the solar short wave radiation but not for the thermal radiation emitted by the soil and plants. This effect causes ten to twenty percent of the temperature rise.

Compared with other buildings a glasshouse is an open system in which the climate is influenced directly by the outdoor climate. But compared with the climate in the open, the glasshouse climate is that of a closed system in which the heat and vapour exchange inside directly influences the climate. So both a transition from outdoor to indoor climate and a description of plant behaviour is needed to determine the environmental factors near the plant. These factors in turn determine plant behaviour so only a description of the total system will be successful.

To understand the heat and mass transfer between plants and atmosphere a short description of this aspect of plant behaviour is essential. The main plant processes involved here are photosynthesis and transpiration.

Photosynthesis is determined as main factor by short wave radiation, carbon dioxide concentration and temperature. Only a small, almost negligible amount of the short wave radiation is directly absorbed in the photosynthesis process. The main part is

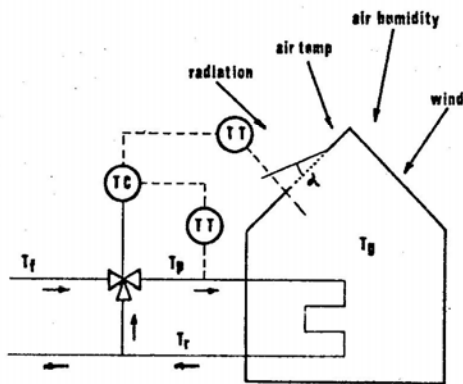


Fig. 1. Heating system control loop.

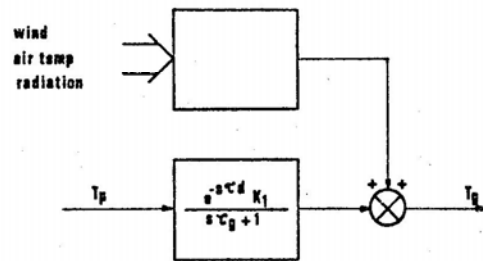


Fig. 2. A dynamic model of the heating system.

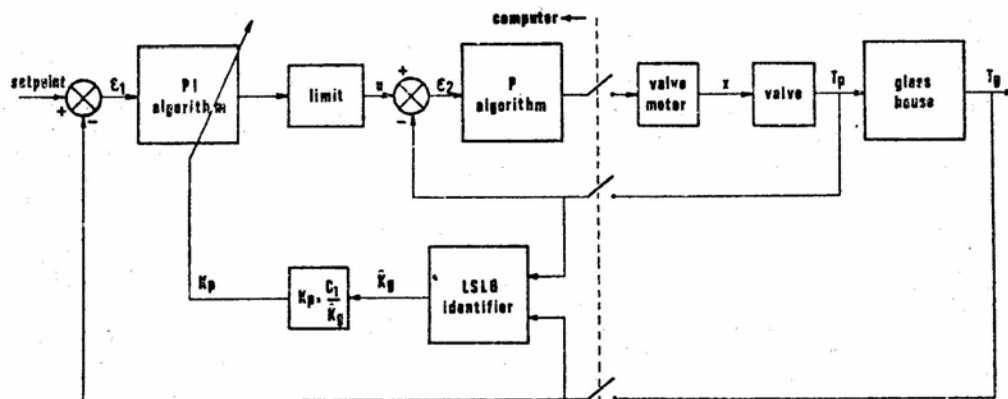


Fig. 3. Heating system control loop.

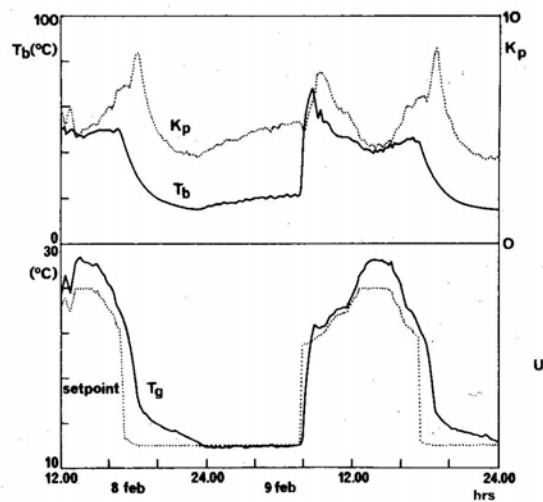


fig. 4. Results of a field test at Feb. 8, 1977.

absorbed by the leaf, leading to a temperature rise of the leaf. To prevent a too large temperature rise it is cooled by transpiration, the water being transported from the roots to the inner parts of the leaf and then evaporated to the atmosphere.

For the absorption of carbon dioxide and the evaporation of water vapour, the leaf has small holes or stomata in the surface. For photosynthesis these holes have to be wide to support carbon dioxide. In this situation, however, water *is* evaporating producing a possible water shortage in the leaf. To control these phenomena the aperture of the stomata is regulated by internal plant processes, dependent on photosynthesis, transpiration and water content of the leaf (4, 5) which in turn are dependent on the local environmental factors.

Adaptive control The control problem

To introduce the adaptive controller (1), the control problem has to be defined. It is recalled that the glasshouse climate is influenced by the external factors showed in fig.1, where also the heating system control loop is given.

The objective of the heating system is to regulate the glasshouse temperature T . This temperature is influenced by the external factors and can be manipulated by ventilation which is caused by the position (with angle ϕ) of the control windows and by regulating the heating pipe temperature T_p . The control problem can thus be regarded as multi input process. The inputs are the control variables ϕ and T_p the output is the controlled variable T . The characteristics of this process are highly influenced by the external factors, in order to prevent heat losses it is desirable to manipulate T_p , since manipulating of ϕ cause opening of the windows and subsequent heat loss. Therefore, the control of the windows is separated from the heating system control. Manipulation of ϕ acts as a disturbance for the heating system control. Usually the setpoint for the window control is set higher than the heating setpoint so that interaction of both control loops is decreased to an acceptable level from control theoretical point of view and heat loss is prevented.

In the heating control loop, the heating pipe temperature is controlled by a three way valve that mixes the return water with temperature T_r with the feed-water from the main boiler with temperature T (fig.1). The response of T_p on a change of the valve position is relatively fast if T_p has to increase, but slow if T_p has to decrease. The cooling response of the valve is rather slow. Since the temperature fall is dominated by T_r and T_p decreases slowly because of the large heat content of the pipe water, the position of the mixing valve is in fact the proper control variable but is not selected because of the asymmetric relation between the valve position and T_p . This allows the selection of a simple control model, that produces specific control problems when large transients of T_p are required.

A simple model

In order to design a control loop it is necessary to construct a dynamic model of the heating system. When the partial differential equations governing the heat (and vapour) flows from the pipes into the glasshouse are lumped into an approximate simple linear first order transfer function with a time delay, a dynamic model results as shown in fig.2, with input T_p and output T_g . In this model the external influences are included following Root (6). Experiments were performed in the Naaldwijk glasshouse that consists of 24 identically, individually controlled compartments of 56 m² each. Under different conditions typical results for the parameters of the simple model of fig.2 were: time delay $T_d = 6$ minutes, the time constant of the first order model $T_g = 30$ minutes and associated gain $K_1 = 0.25$ to -0.5 ; T_d and T_g being fairly constant. The external factors cause a disturbance signal, of which the significant part is relatively slowly time varying. It is therefore assumed in this paper that the offset caused by the external influences and the dynamic gain K_1 can be lumped together producing a time variant gain K_g . This gain K_g is not easily determined because the dynamic model of fig 2 assumes known offsets on T_p and T_g . Usually a model is defined by linearization around a nominal operation point. In

the glasshouse this point is subject to large variations so that this approach cannot be used. Therefore, zero offsets were assumed producing a gain K related to a static plus dynamic model. In the Naaldwijk glasshouse typical values of $K = 0.2-1.0$.

The adaptive control loop (fig.3)

In the adaptive controller of fig.3 the adaptation compensates for variations in K, which means that K has to be computed from input-output observations. This is performed by a recently reported "least squares like gradient" identification technique (7), that is physically similar to the well known recursive least-squares technique (8).

In the identification procedure, the simple model of fig.2 is discretized and K_g is estimated. The estimate K_g of K_g is used to adjust a PI (proportional plus integral) algorithm that is a discrete version of the continuous PI controller with input signal e and output u :

$$u = K_p \left(e + \frac{1}{T_i} \int_0^t e(\tau) d\tau \right) \quad (1)$$

The time constant $T_i = 25$ min. The gain K_p of the PI controller is varied proportional to the inverse of the gain K_g , thus keeping the product $K_p K_g$ constant. The signal u acts as setpoint for the Pipe temperature control (fig.3). In the controller, the signal u is limited between the minimum and maximum T . The values of T_p min/max are time-varying and are based on horticultural requirements as well as on practical control considerations.

Field results

The adaptive control algorithm was programmed in the computer at Naaldwijk. Fig.4 gives some results on february 8, 1977. The weather conditions on that day were: sunny, mean outside air temperature = 7°C, mean wind velocity 5 m/s.

Shown are the responses of the adaptive gain K_p , T_p , T_g and the setpoint of T : the setpoint is varied according to the amount of light. From the results it can be concluded that the controller follows the setpoint satisfactorily. An advantage of the adaptive control is that the value of the product $K_p K_g$ it was selected in January 1977 and since then (in May) there has been no reason to tune the controller for warmer weather conditions.

The responses stress the interesting features of the adaptive controller: after an initial tuning the controller is continuously and automatically adapted to varying weather conditions, leading to a control loop that is insensitive to external influences. It is remarkable that this successful adaptive control is based on an almost too simple model of the glasshouse heating dynamics. On the other hand, the choice of this particular simple model and the detailed configuration are based on quite some engineering knowledge which makes the simple model rather the product of the design procedure than the starting point.

Climate model

In the climate model the heat and water vapour flows are considered in a compartmented glasshouse.

The compartments in the model are the glass cover, the inside air, the plants (or canopy), and some layers in the soil.

This is only a rough compartmentation, but measurements justify this approach for a model which only includes total heat and mass exchange of the canopy.

The main incoming energy flow is short wave solar radiation. Sometimes a glasshouse is regarded as a large radiation collector, converting solar energy into plant production. The incoming solar energy is partly absorbed, reflected and transmitted by the glass roof and walls. The transmitted radiation is again partly absorbed,

reflected and transmitted by the canopy and then by the soil. From the known optical properties of the cover, the canopy and the soil, the total absorbed amount of incoming solar energy is determined. In the model the optical properties were assumed to be constant, though the reflection, which is dependent on the direction of the incoming radiation is changing during a day and during a year. For the glasshouse under consideration the absorbed percentages were 40% for the cover, 27% for the canopy and 16% for the soil, 12% was reflected directly by the cover and the remaining 5% was reflected by the canopy and the soil and transmitted to the atmosphere.

The incoming thermal or terrestrial radiation is described in literature by empirical formulas because of the complexity of the mechanism. WATERNA (9) reviewed various methods and compared them with measurement data. The results turned out to be so inaccurate that it is not justified to include terrestrial radiation in the model. Under certain meteorological conditions however, e.g. in clear nights without wind, or even on clear days, this will be a shortcoming.

On the contrary, thermal radiation exchange in the glasshouse between cover, canopy and soil is of interest. Because of the relatively small temperature differences, the Stephan BOLTZMANN formula is linearised.

As stated in the discussion on the "greenhouse effect" the reduction of the turbulent exchange is of main importance. The related transport process in ventilation, transporting both heat and water vapour to and from the air compartment.

The incoming heat flow by ventilation $\psi_{h, \text{vent. in}}$ is given by :

$$\psi_{h, \text{vent. in}} = \psi_v \rho_p c_p T_{\text{out}} \quad (2)$$

The incoming water vapour flow $\psi_{w, \text{vent. in}}$ is also determined by ψ_v according to:

$$\psi_{w, \text{vent. in}} = \psi_v (m / R T_{\text{out}}) e_{\text{out}} \quad (3)$$

The same formulas with of course T_{in} and e_{in} instead of T_{out} and e_{out} are valid for the outflowing heat and water vapour flow.

The amount of exchanged air ψ_v is dependent (see fig.1) on the position of the window, the outside wind velocity and direction, and to a lesser degree on the temperature difference between in- and outside air.

Satisfying relations are not reported in literature. We started model experiments in a windtunnel to find the relation between air exchange, window position and wind velocity. Full scale experiments should validate the results.

In the present model ψ_v is based on forced ventilation data or estimations in a natural ventilated glasshouse.

In the model the mechanism of convection is treated in the usual way by using dimensionless relations. For the convective exchange between cover and outside turbulent airflow, the heat transfer coefficient is assumed to be (10):

$$Nu = 0.03 Re^{0.8} \quad (4.a)$$

$$\text{resulting in } \alpha = 5.5 v^{0.8} l^{-0.2} \quad (4.b)$$

with air properties at about 10°C. Determining a more accurate relation is not so interesting, since the largest convective resistance exists between cover and inside air. Inside the glasshouse a combination of circulation and free convection is present along the glass, due to the temperature difference between glass and inside air. The natural convective heat transfer coefficient between a vertical wall and inside air is for the turbulent region given by :

$$Nu = 0.1 Gr^{1/3} Pr^{L/3} \quad (5.a)$$

resulting in:

$$q = 0.125 (\Delta T)^{1/3} \quad (5.b)$$

The forced convective heat transfer is still given by (4).

For the low inside air velocity of about 0, 1-0, 25m/s the forced and free convective heat transfer have about the same magnitude. The result is a heat transfer coefficient of about 5 W/m²K. For the almost horizontal roof (an angle of 26° between roof and horizon is applied for a common type of glasshouse), the natural convection will be somewhat smaller, the total result however will be similar. So the inside heat transfer coefficient is fixed to a value of 5 W/m²K. More accurate figures can be expected when the inside circulation as a function of ventilation and natural convection along the heating pipes is determined. In the present research programme on ventilation this subject is pursued. For the convective heat transfer between inside air and soil, natural convection will be the most important mechanism, the circulation is decreased in the canopy. Therefore, a heat transfer coefficient of 3.5 W/m²K is selected. Along the leaves forced convection will dominate. A great variety of relations is found in literature (11):

$$q = (4 \text{ à } 13) v^{0.5} l^{0.5} \quad (6)$$

This might be motivated because the relations with the low coefficient have to be applied on both sides of the leaf but in the relations with the high coefficients both sides of the leaf are already incorporated. This is however not always stated clearly. As a compromise $q = 5 (v/l)^{1/5}$ is used, applied on both sides of the leaf. With low windspeed of about 0.1 m/s and a leaf width of 5 cm, q will be 7 W/m²K.

The convective mass transfer coefficient k is related to the heat transfer coefficient α according to

$$k \approx q / \rho c_p \quad (7)$$

So in the water vapour model the convective mass transport is determined from the convective heat transport in the temperature model. For the plant compartment we have taken into account the stomatal resistance according to section 2.

In the soil, heat transfer by conduction is considered between the soil compartments. Due to the assumed constant water content of the soil (in glasshouses the soil is kept moisty) the heat conductivity is assumed constant at 2 W/mK.

BOND GRAPH REPRESENTATION AND INTERACTIVE SIMULATION

The relatively novel bond graph notation (12, 13) is chosen for the representation of the model for the following reasons:

- it represents the physical structure in an easily recognisable, compact way
- computational problems can be detected and remedied in the bondgraph
- it is readily converted in a simulation programme, suited for interactive simulation by using the block oriented simulation language THTSIM (14). Moreover it can also easily be translated into a set of differential equations, that can be solved by programming in CSMP;

Fig.5 shows the bond graph of the simplified glasshouse model. The nodes or "0-junctions" represent the distinct temperatures or vapour pressures in the model. The line elements or "power bonds" correspond with energy flow, the half arrow indicating the prescribed positive direction. A bond is actually a shorthand notation for the interaction between components and involves two signals.

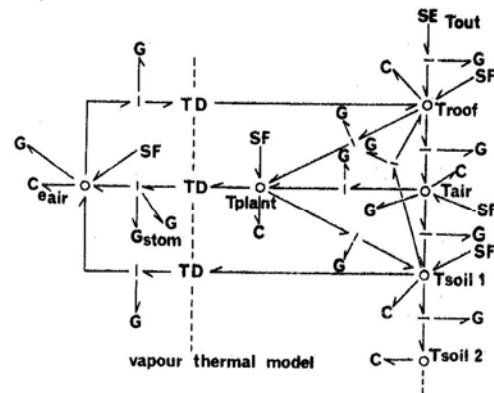


fig. 5. Bond graph of simplified glasshouse

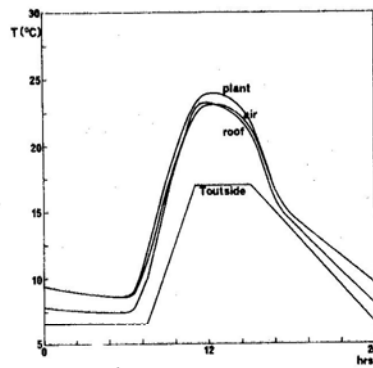


fig. 6. Some temperatures over 24 h. in an unheated glasshouse

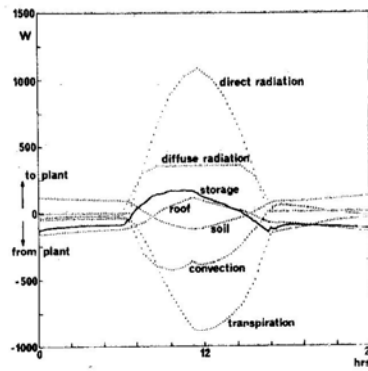


fig. 7. Terms of the energy balance of the plant compartment

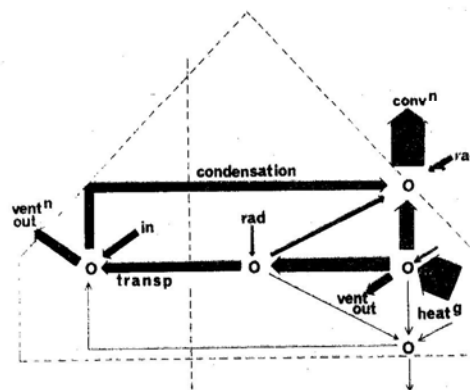


fig. 8. Temperatures and heat flows during a cold rain shower

On the top of the right side or thermal part of the model the direct and diffuse radiation is represented by a time dependent source of heat flow (SF), acting on the heat capacity (C) of the roof. From this "T roof" the heat flows in several directions via "1-junctions" to which heat transfer components "C" are connected. The G's represent the linear or non linear heat transfer by conduction (in the soil), by convection and by radiation. On the bottom right side the heat flow is seen to enter a regular conductance-capitance network representing the compartmented *soil*.

The left side of the bond graph is the vapour model. There the mass balance of the vapour in the inside air is represented by the vapour capacity C, with its associated state variable e_a . An incoming flow source SF and an outgoing G represent the vapour which comes in and goes out by ventilation.

The coupling between the vapour and thermal parts of the model involves evaporation or condensation at the soil surface (lower coupler) and at the plant surface (middle coupler). At the glassroof (top coupler) only condensation takes place. The couplers are represented by transducers (D). Due to the interactive nature of the energy exchange each TD represents two relations: one between the vapour pressure and its associated temperature and one between the vapour mass flow and the corresponding latent heat flow.

The stomatal behaviour is incorporated in the non-linear **Gstom** component.

A more detailed description of the bond graph model and its simulation is given in a previous paper (2). The TRTSIM programme accepts the bond graph structure in a simple way. When the constant or time dependent parameters of the components and the simulation control data (timing, plot outputs) are specified the numerical or plotted response can be obtained. The user keeps all the time in touch with components and a structure having a physical meaning.

Simulation results are shown in figs. 6, 7 and 8. The temperatures of the outside air, the cover, the air, the plant and the upper soil-layer compartment are given in fig. 6. The glass temperature has a value between that of the inside air and outside air at night, by day it has nearly the same value as the inside air temperature though the outside heat transfer coefficient is much higher than the inside one. This is caused by the high rate of radiation absorption. By day, the plant temperature is a few degrees higher than the air temperature, at night they are nearly the same. The adjustment of the plant temperature is given in fig. 7. In the daytime, incoming radiation is mainly compensated by transpiration. The thermal radiation to and from the soil and the glass nearly compensate each other. Also for varying weather condition simulations can be made.

Fig. 8 shows the heat flows and temperature at one moment during a cold rain shower. It is represented in a formalised bond graph way (Sankey diagram), constructed from the printer outputs.

This type of diagram gives a good insight in the heat and vapour flows in the system under varying conditions.

CONCLUSIONS

Optimal plant growth is formulated as a hierarchical control problem with three control levels. At the first, basic, level the systems approach was successfully applied by using a simple approximation for the glasshouse dynamics in an adaptive heating control system. A physical climate model is promising for application in a control algorithm for both heating and ventilation. This model is kept simple because it is applied in a closed control loop and it is not yet possible to quantify accurately all involved transport processes. By sensitivity analysis, the sensitive parts of the model can be located. For control in the second level, not only plant exchange but also plant processes have to be included in the model. Presently, plant behaviour can be described as a function of the environmental parameters and used in the simulation of the microclimate (15). At the third level, a lot of horticultural knowledge is available, but only in static form. In the systems approach dynamic optimization has to be performed. A first attempt is published recently (16).

REFERENCES

1. UDINK ten Cate, A.J. and VORREN, J.J.van de. Digital Adaptive Control of a Glasshouse Heating System. Preprints 5th. IFAL/IFIP Int.Conf.on Digital Computer Applications to Process Control. The Hague, June 1977, pp.507-512.
2. BOT, G.P.A. and DIXHOORN J.J.van, Bond Graphs and Minicomputers in the Research of Greenhouse Climate Control. Paper presented to EPPO/IOBC Conf.on Systems Modelling in modern Crop Protection.Paris Oct.1976.
3. LEE, R. The Greenhouse Effect-J.Appli.Meterol.12 (1973) pp.556/557.
4. RASCHKE K., Stomatal Action. Ann.Rev.Plant Physiol.26 (1975) pp, 309-340.
5. TAKAKURA T., GOUDRIAAN J. and LOUWERSE W., A Behaviour Model to Simulate Stomatal Resistance .Agric.Meteorology 15 (197) pp.353-404.
6. ROOTS W.K., Fundamentals of Temperature Control.Ac.P., New York (1969).
7. UDINK the Cate, A.J.and VERBRUGGEN H.B.Least-squares Like Gradient Method for the Identification of Discrete Processes. Rep. to be published.
8. EYKHOFF P., System Identification.Wiley London (1974).
9. WARTENA L., PALLAND C.L. and VOSSEN G.H.van de, Checking of Some Formulae for the Calculation of Long Wave Radiation from Clear Skies.Arch.Met.Geoph.Biokl. Ser.B 21 (1973) pp.335-348.
10. WARMEATIES V.D.I. ed.2.Berechnugblatter far den Wirmeabergang.VDI Verlag GmbH. Dusseldorf 1974.
11. STIGTER C.J., Leaf Diffusion Resistance to Water Vapour and its Direct Measurement. 1.Meded.LH, Wageningen 72-3 (1972).
12. KARNOPP D.C.and ROSENBERG R.C., System Dynamics:A Unified Approach, Wiley New York 1975.
13. OSTER G.F., PERELSON A.S., KATCHALSKY A.Network Thermodynamics:dynamic modelling of biochemical systems.Quaterly Review Biophysics 6 (1973) pp.1-34.
14. KRAAN R.A., THTSIM=A Conversational Simulation Language on a Small Digital Computer, Journal A 15 (1974) pp.186-190.
15. GOUDRIAAN J.Crop Meteorology:A simulation Study.Pudoc, Wageningen.diss.LH, Wageningen 1977.
16. CHALLA H.An Analysis of the Diurnal Course of Growth , Carbondioxide Exchange and Carbohydrate Reserve Content of Cucumber.Agric.Res.Rep.861.diss.LH, Wageningen 1977.

I XII. DIFFERENCES IN RESPONSE OF PLANTS GROWN UNDER CONTROLLED
CONDITIONS AND IN THE FIELD

J.E.BEGG .CSIRO.Division of Plant Industry
P.O.Box 1600 Canberra City ACT 2601.Australia

Editorial Note.The author of the article "Crop Water Deficits", which appeared in ADVANCES IN AGRONOMY (28, 1976, p.161-217), has made an extract of one chapter which we here print since it will interest many readers.

X

There is an increasing body of evidence building up in the literature indicating that the response functions of plants grown in controlled environments differ from those grown in the field, particularly in response to water deficits (EVANS). For example, the growth responses of maize, sunflower, and soybean to a decline in plant water potential in growth chambers reported by BOYER (1970a) and ACEVEDO et al.(1971) differ from those of field grown plants(CARY and WRIGHT, 1971; RITCHIE 1973, 1974; BURNER and BEGG 1973; WATTS 1974). The growth chamber data indicated a marked reduction in leaf expansion in maize ψ leaf decreased from -2 to -4 bars with complete cessation of growth at -7 to -9 bars, whereas the field data have shown that a decline in leaf water potential to -8 or -9 bars had little apparent effect on the rate of leaf expansion (fig.5) and leaf growth did not cease until about -17 bars in sorghum (McCREE and DAVIS 1974). The data of WATTS (1974) and McCREE and DAVIS (1974) also indicated that leaf expansion continued day and night at the same rate despite a diurnal change in leaf water potential from -1 to -7 or -9 bars. This apparent insensitivity of field grown plants to low ψ leaf could be due to differences in ψ leaf and to gradients of ψ within the leaves. Cells enlarge in response to the turgor component of ψ ; thus the field and controlled environment plants may have similar P values at these differing values of ψ if the osmotic potentials were lower under the higher light environments of the field. In addition, large gradients in water potential can develop in actively transpiring leaves in the field (YANG and de JONG, 1971) so that the water potential measured on the exposed leaf lamina would have been lower in the field plants than the water potential at the base of the leaf where cell enlargement was taking place. The possibility of osmotic adjustment and the development of ψ gradients would have been minimal in BOYER'S work as the plants were placed in a dark humid chamber in order to measure rate of leaf enlargement over a 24-hour period at a constant leaf water potential.

Both BOYER (1970a) and ACEVEDO et al.(1971) have shown that as stress developed leaf growth stopped before photosynthesis was noticeably affected, and that photosynthesis declined markedly below -8 bars and was very low at -16 bars. As was the case with leaf growth, the water potential at which photosynthesis and stomatal conductance rapidly decline, is lower in field grown plants. JORDAN and RITCHIE (1971) found that the stomatal conductance of cotton decline rapidly in growth chamber plants at -16 bars while the stomatal conductance of field grown plants remained high even at leaf potentials of -27 bars. Similar differences in response by field and growth room plants have been reported for maize (RITCHIE 1973), sorghum (McCREE 1974) and vines (KRIEDEMANN and SMART 1971) and have been discussed by TURNER (1974a), RITCHIE (1974) and LUDLOW (1976).

LUDLOW and Ng (1976) determined response functions for green panic (Panicum maximum var. trichoglume) grown in pots in controlled environment rooms and outdoors. The growth chambers were programmed to simulate the average outdoor values for daylength,

maximum and minimum temperature, and relative humidity. Photosynthetically active radiation was 66% of that received outdoors during a 3-week period without rain. The leaf water potentials at which stomatal conductance decreased substantially (-6 bars) and at which both leaf elongation and net photosynthesis ceased (ca. -12 bars) were similar for both growth room and outdoor potted plants. Thus any possible difference in response by growth rooms versus field grown plants that may be associated with the constancy or "artificiality" of square wave "climates" in controlled environments could be minor compared with the differences associated with restricting the roots in small containers and thus accelerating the rate of onset of stress when water is withheld.

A number of workers have drawn attention to the differences between pot experiments and studies carried out on deep field soils in terms of the rate of development of moisture stress: HAGAN et al. (1957), FISCHER and HAGAN (1965), SALTER and GOODE (1967), JORDAN and RITCHIE (1971), RITCHIE (1974), and LUDLOW and Ng (1976). The roots of field grown plants usually have access to large volumes of soil than those

growing in small pots and once most of the water in surface horizons have been extracted, more water is obtained as the plant grows and roots extend into deeper soil. Even when the roots reach the lower parts of the soil profile, more water is extracted from the upper part of the profile because the root density is usually greater and the specific free energy of the water near the surface makes it more accessible than water deep in the profile. Thus the development of stress during a drying cycle is more gradual in a field grown plant, and the possibility of overnight recovery is greater as it may still have access to water in the lower part of the profile. Whereas in the small pots used in most growth chamber and glasshouse experiments, the root density is high and the entire root system of the plant is subjected to a uniformly increasing moisture stress with relatively little capacity for overnight recovery during a drying cycle. Thus the plant water potential decreases rapidly and the plant experiences a severe water deficit as evidenced by stomatal closure and marked reduction in photosynthesis.

In the field, the more gradual transition from mild to severe stress allows time for further root development and osmotic adjustment during the early stages of stress when the rate of cell enlargement and possibly leaf area is reduced, but not the rate of photosynthesis. The point missed by many short-term physiological experiments is that there is more time for field grown plants to adapt to developing stress, and that in a field crop, growth is initially reduced by a reduction in leaf area well before there is a reduction in photosynthesis (FISCHER and HAGAN 1965). Also any reduction in leaf area causes an irreversible reduction in growth in a determinate plant, whereas a reduction in the rate of photosynthesis is only temporary and photosynthesis can recover on relief of stress.

Thus one of the major limitations of controlled environments for plant-water relations studies could be overcome by using soil containers that allow for more realistic root development in volume and depth. This is not to detract from the importance of providing higher light in the photosynthetically active, 400-700 nm waveband, and more realistic soil temperatures in controlled environments. In this context the thermal mass of a large volume of soil will assist in achieving more realistic soil temperature in growth rooms.

A consequence of osmotic adjustment and the differences in response between field and controlled environments is that much of the data obtained in controlled environments cannot be applied directly to the field situation. For example, from the controlled environment studies of BOYER (1979a, b), both stomatal conductance and the rate of photosynthesis in maize decreased at values of ψ_{leaf} below -8 bars and were very low at -16 bars. Thus, at values of ψ_{leaf} of -12 to -15 bars observed in well-watered maize in the field, stomata might be expected to be closed and photosynthesis low; this was not the case (TURNER and BEGG 1973). An example of the application of controlled environment data to the field situation leading to an unlikely

conclusion is provided by REICOSKY et al.(1975).They concluded that in maize, "leaf growth rate decreased considerably as the sun rose, almost stopped by 0800 , and did not resume till almost sunset".This conclusion was based on the controlled environment data of BOYER (1970a) and ACEVEDO et al.(1971) indicating that the leaf elonga tion rate in maize was essentially zero at values of ψ_{leaf} below -7 bars, and their own field measurements of ψ_{leaf} . However, in the light of field observations by WATTS (1974) showing no apparent effect of ψ_{leaf} values above -9 bars on leaf elongation rate, it is unlikely that elongation ceased during the day in their study. Clearly, simulators of crop growth and development in the field must use caution when making use of short-term response data obtained from plants grown in controlled environments.

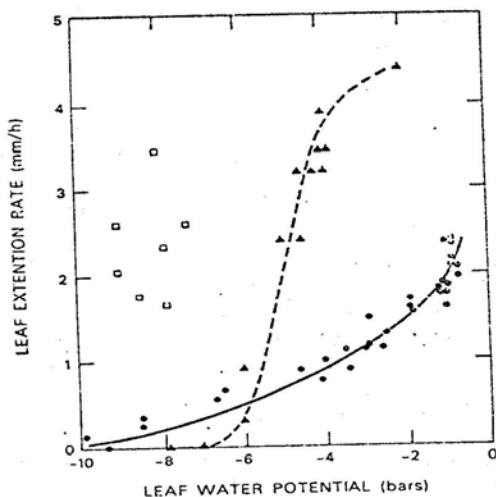


FIG. 5. Relationship between leaf extension and leaf water potential for maize grown in the field (\square), or grown in controlled environments in the dark at 28°C (\bullet), or in the light at 30°C (\blacktriangle) (from Watts, 1974).

REFERENCES

- ACEVEDO E., HSIAO T.C. and HENDERSON D.W.1971. Plant Physiol.48, 631-636.
 BOYER J.S.1970a.Plant Physiol.46, 233-235.
 BOYER J.S.1970b.Plant Physiol.46, 236-239.
 CARY J.W. and WRIGHT J.L.1971.Agron.J.63, 691-695.
 EVANS L.T. in "Climate and Rice" Proc.Climate and Rice Symp.1974, I.R.R.I.Los Banos, Phillipines (in press).
 FISCHER R.A. and HAGAN R.M.1965.Exp.Agric.1, 161-177.
 HAGAN R.M., PETERSON M.L., UPCHURCH R.P. and JONES L.G.1957.Soil Sci.Soc.Am.Proc.21, 360-365.
 JORDAN W.R. and RITCHIE J.T.1971.Plant Physiol.48, 783-788.
 KRIEDEMANN P.E.and SMART R.E.1971.Photosynthetics, 5, 6-15.
 LUDLOW M.M.1976.in "Water and Plant Life Problems and Modern Approaches" (O.L. Lange, L.Kappen and E.D.Schulze eds) Springer Verlag.Berlin and New York (in press)
 LUDLOW M.M. and Ng T.T.1976.Aust.J.Plant Physiol.3, 401-413.
 MCCREE K.J.1974.Crop Sci., 14, 273-278.
 MCCREE K.J. and DAVIS S.D.1974.Crop Sci.14, 751-755.
 REICOSKY D.C., CAMPAELL R.B.and DOTY C.W.1975.Agron.J.67, 380-385.
 RITCHIE J.T.1973.Agron.J.65, 893-897.

- RITCHIE J.T.1974.Agric.Meteorol.14, 183-198. TURNER
N.C.1974a.R.Soc.N.Z.Bull 12 423-432. TURNER N.C. and
BECG J.E.1973.Plant Physiol., 51, 31-36.
WATTS W.R.1974.J.Exp.Bot., 25, 1085-1096.
YANG S.J. and de JONG E.1971.Can.J.Plant Sci.51, 333-336.

x x

x

XIII. PROBLEMS OF GROWTH ANALYSIS IN CONTROLLED ENVIRONMENTS

H.KRUG, Institute of Vegetable Crops.Technological
University of Hannover. Herrenhauser Str.2 , 3000 Hannover
2I-GFR.

Research on plant physiology and plant production in controlled environments has greatly developed over the last 50 years. In the industrialized countries there is hardly any university or research station, engaged in biological problems, which does not possess a phytotron or similar equipment. This development results out of the need- after having successfully explored the actions of plant nutrients, water and other easily controllable growth factors- to investigate the action of the climatic growth factors using the advanced techniques. This does not exclude, that occasionally, as in other research fields, the wish to be modern and prestige-thinking have contributed to this rapid progress.

After having investigated many millions of dollars and conquered the first difficulties, enough experience has been gained to examine critically, for what research work controlled environments can be used, which problems arise with respect to the simulation of the growth factors, with artificial, mostly simplified programs of the climate, and hence, what are the consequences for the validity of the results.

Use of controlled environments in plant production research

In plant production research controlled environments are used for different purposes:

1.to produce reproducible, favourable, or only constant growth conditions.Examples are:

The breeder can enhance reproduction and hence the breeding program.The time from sowing to flowering of *Asparagus officinalis*, for example, takes about two years in the field, 1 year in greenhouses and can be reduced to 4 months (30/35° C, high radiation) in growth chambers.

In growth chambers plants can be selected independently of the season and environmental conditions can be used to intensify the selection or to enable a preselection. In France growth chambers are used for variety studies (CHESNEAUX, 1975).

In plant protection research growth chambers are used to give reproducible, constant or intensified predispositions for infection experiments or for testing the phytotoxicity of herbicides (DARWENT and BEHRENS 1972).

In plant production research growth chambers are useful tools to raise plant material for a determined time.

In these cases, the use of growth chambers is not free of problems. Their usefulness, however, is out of question.

2.To analyse stress conditions for plant growth, which occur irregularly or only seldom in nature, as for example cold, heat or dryness. The advantage of using growth chambers for these experiments is obvious: the experiments are almost independent of time and site. On the practical usefulness of experimental results concerning

stress conditions in growth chambers I have no information. But I believe that the problem involved can be solved, since in stress conditions the reaction of the plant is mostly governed by only one growth factor. Therefore the reactions are easier to interpret and the action of the growth factor in nature can more easily be simulated at an acceptable expense. There remains, of course, an "unnatural" remainder complex and the results have to be controlled in natural conditions.

Furthermore growth chambers enable research on conditions which do not occur with the overground organs of higher plants in nature, such as low concentrations of oxygen. Experiments in this field improve our physiological knowledge and can be used for plant storage.

3. The main interest of plant production research in controlled environments are experiments on the kinetics of plant reactions to one or more climatic growth factors to optimize plant production procedures. The problem is that the action of each growth factor depends on the action of every other growth factor. All the growth factors together act in a complex which is difficult to analyse. To clarify this, on the one hand, the growth factors should be simulated quantitatively and qualitatively as far as possible or financially acceptable. On the other hand, however, it remains to be decided how far the fluctuating climatic conditions have to be simplified to facilitate or enable the analysis, and still to obtain relevant results.

Physical problems with simulating growth factors

The radiation conditions in growth chambers deviate more or less from those in the field, depending on the expenditure and the skill of the research worker. The problem with the spectral energy distribution of the lamps are well known. These are mostly recognised with respect to photosynthesis, but they are equally important with respect to the radiation balance and photomorphogenesis of the plant.

The problems involved in the radiation balance are discussed by IDLE (1965) and ORCHARD (1967) and growth chambers to control this factor are described. Since these constructions are rather expensive, at least the lamp cabinet should be artificially temperature-controlled, to avoid seasonal fluctuations of the temperature and hence radiation of the glass panel (see YAMAMOTO and SAKURATANI, 1975). Photomorphogenetic effects of light quality are frequently discussed in the botanical literature. Information on the quantitative action on growth and yielding is scarce (s. ACOCK, 1974; DEUTSCH and RASMUSSEN, 1974). The best adaptation to sunlight is achieved by Xenon lamps. These, however, are very expensive in the primary and running costs. The advantages and disadvantages of high-pressure-meta-halide lamps, high-output sodium lamps or high output fluorescent lamps are difficult to judge.

With respect to light flux density in growth chambers with high output fluorescent lamps (VHS Sylvania 215 W Coolwhite and White, supplemented with 18% total wattage incandescent lamps) several vegetables (tomato, cucumber, lettuce, cauliflower) showed an "abnormal", stunted growth, hairy leaves and partly a chlorosis with light flux densities above 25 klx for 16 hours (KRUG and WIEBE 1972). This effect could not be diminished efficiently by an UV filter or more incandescent light. Though light flux densities up to the maximum value of the site are desirable (Hannover about 5000 Wh.m⁻²d⁻¹ or 525 lx.h), the benefit of these high light flux densities is questionable. More experiments in this field are necessary with other lamps, and more consideration should be paid to the growth behaviour in the field.

More attention should be given to the light climate within the crops. In the field the vertical light gradient inside the canopy only depends on the shading of the plants. In growth chambers, however, this gradient is superimposed by the vertical light gradient of the empty chamber, due to the absorption of the walls. This gradient measured about 130 lx.cm⁻¹ up to 1, 2 m below the plexiglass panel in the growth chambers described earlier (KRUG and WIEBE 1972). With high plants it may increase leaf senescence in the lower zone of the canopy, due to a decreased photosynthesis. In addition to this light action it has to be considered, that the light source does not circulate in the sky. The light and the shadows are fixed, without compensation during the light period.

A growth chamber with natural day light (NEUBAUER and ZSCHEILE 1966), which overcomes some of the light problems by following the sun and thus securing high light intensities in the light climate of California, is rather sophisticated, very expensive and other problems with air conditioning remain.

Other difficulties in simulating outdoor growing conditions arise because of the air velocity. In common growth chambers a relatively high air velocity is needed to remove the heat energy by radiation. Wind speed, however, influences leaf temperature, transpiration rate, CO₂-diffusion rate, and hence the action of these growth factors. A lower air speed can be achieved by cooling the walls of the growth chambers (REICHART, 1965). This equipment, however, is more expensive, and other problems, such as different radiation balance of the plants depending on their position in the growth chamber, arise.

Physiological problems with simplified climatic programs

I do not agree with DOWNS and HELLMERS (1975), that the simulation of natural climatic conditions is senseless, since these experiments could be run in the field. Fluctuating, but controlled environments have the advantage of being reproducible independently of site and season. They are suitable to test cultivars, the action of chemicals or production procedures. In addition, they enable the running of a climate on different levels, for example the average temperature course with + 5° C and/or -5 C (BRETSCHNEIDER-HERRMANN, 1974). They permit the changing of one or more growth factors, to simulate for instance cold periods (s.HACKEL 1970- or to test the reaction of the plants during special growth phases, in otherwise almost "natural" growing conditions.

The results of such complicated climatic programs, however, are closely connected to the conditions used, that means to special climates and seasons. They are difficult to evaluate, to interpret, to generalise and to transfer to other climates. Hence a simplification of climatic programs often is desirable. The question is, to what extent simplification should be practised to facilitate the evaluation, to improve the generalisation, but to receive results which are relevant for field or greenhouse conditions.

The most extensive simplification is to maintain constant conditions of all growth factors. Experimental results, however, show that some species do not grow "normally" in these environments. Peas, for example, show decreasing growth rates at constant temperatures from generation to generation (HIGHKIN 1958), tomatoes suffer from chlorosis at continuous light at medium or high temperature (HILLNANN 1956). A constant water potential in cauliflower plants leads to calcium deficiency and a decay of the curd (KRUG a.o. 1972). Some plants grown in constant temperatures as well as in environments with diurnally fluctuating temperatures with the same temperature mean. This is reported for some ornamentals (*Saintpaulia ionantha* HILDRUM and KRISTOFFERSEN 1969; *Codiaeum*; *Hedera*, *Rhoicissus*, *Peperomia*-SANDVED 1974) and radish (KRUG, unpubl.). This statement only holds true for a medium range of temperatures with an almost linear relation between temperature and growth, but not if extremely, high or low temperatures prevail for some time during day or night. With some cruciferes we observed a lower growth rate, or a more frequent decay of young organs at constant low temperatures in growth chambers, than in fluctuating conditions in the field (KRUG and FOLSTER 1974).

With another group of plants, the growth rate is evidently promoted by a diurnal temperature rhythm. This is shown for germination (see MAYER and POLJAKOFF-MAYBER 1963; THOMPSON 1974; HEGARTHY 1974) and/or autotrophic growth after emergence (WENT 1957, 1961; KNAPP 1956; BRETSCHNEIDER-HERRMANN 1977). Younger plants mostly react less than older plants. A very pronounced reaction is shown for lettuce (VERKERK and SPITTERS 1973). In the experiments of WIEBE and LORENZ (1977) lettuce plants were even more promoted with a continuous rise and fall of temperature, as it occurs under natural conditions, compared with an abrupt temperature change between day and

night. The negative effect 'of a daily continuous rise and fall of temperature on springwheat was explained by the high maxima (BRETSCHNEIDER-HERRMANN 1974).

In growth chamber experiments with several species, a simulated natural rhythm of light intensity compared with a constant light intensity during daytime-always with the same daily mean-yielded no growth promotion for Chrysanthemum morifolium (HUGHES and COCKSHULL 1971) and tobacco (RAPER a.o., 1973). With lettuce WIEBE and LORENZ (1977) even found a negative reaction. They assume a smaller action of the high light intensity in the range of the peak. The simultaneous rise of light and temperature, as is prevails in the field and in greenhouses, yielded no promotion above that already stated.

Furthermore, in growth chamber experiments the daily course of temperature has to be considered for stimulative processes such as vernalization. In experiments with cauliflower grown in constant temperatures in growth chambers WIEBE (unpubl.) found the same vernalization effect at lower temperatures (2-7°C), a higher effect at medium (7-16°C) and a smaller effect at high temperatures (16-24°C) if compared with field data derived from a growth model. At least the lower effect at high temperature can be explained by the absence of cool night temperatures, which have more than an additive effect (WIEBE 1974).

Other problems arise with simplifying other growth factors, or seasonal changes in climatic conditions, and/or changing plant reaction with aging. BRETSCHNEIDER-HERRMANN (1974) found small differences between a rather subdivided and a more simplified seasonal climatic program with springwheat. On the other hand, clear after effects of the proceeding conditions have been observed (unpublished data). More experiments are necessary before generalizations can be made.

Summarising, it can be stated that growth chambers can be used in many experimental fields in crop science and are a useful tool to analyse plant reactions in natural or plant production conditions. Problems arise concerning to what extent the quality and the quantity of growth factors have to be simulated, and how far the fluctuating weather conditions should be simplified to facilitate the interpretation and generalization of the results. Concerning the growth factors, more attention should be given to the air velocity and uniform air flow, the radiation balance, the climate, especially light climate, inside the crop and, hence, spacing. With respect to the simplification of climatic programs, a diurnal fluctuation of temperature of 5-6°C, or adapted to the site of production, is recommended. A diurnal fluctuation of light intensity during the light period seems of minor importance in the range commonly used.

REFERENCES

- ACOCK B. 1974. The design and use of growth chambers for investigating the effects of environmental factors on plant growth. *Acta Horticulturae* 39, 15-38.
- BRETSCHNEIDER-HERRMANN B. 1974. Effect of some simple temperature programs on springwheat. *Acta Horticulturae* 30, 117-126.
- BRETSCHNEIDER-HERRMANN B. 1977. Zur Wirkung der tages- und jahreszeitlichen Klimaperiodizität auf das Pflanzenwachstum in Klimakammerversuchen. Vortrag anlässlich der Tagung "Klimatisierte Räume als Werkzeuge der Pflanzenbauforschung" Braunschweig.

- CHESNEAUX M.T.1975.Utilization of growth chambers for varietal studies of horticultural species. Phytotronics III, 27-33, ed. by P.Chouard and N.de Bilderling, Bordas, Paris, Bruxelles, Montreal.
- DARWENT A.L. and BEHRENS R.1972.Effect of pretreatment environment on 2, 4-D phytotoxicity. Weed Sci.20, 540-544.
- DOWNS R.J., HELLMERS H.1975.Environment and the experimental control of plant growth. Academic Press, London, New York, San Francisco.
- DEUTCH B., RASMUSSEN O.1974.Growth chamber illumination and photomorphogenetic efficiency. Physiol.Plant.30, 64-71.
- HACKEL H.1976.Zur Temperatursteuerung von Klimakammern auf der Basis klimatologischer Daten.Gartenbauwiss.41, 186-190.
- HEGARTHY T.W.1975.Effects of fluctuating temperature on germination and emergence of seeds of different moisture environments.J.exper.Bot.26, 203-211.
- HIGHKIN H.R.1958.Temperature induced variability in peas.Amer.J.Bot.45, 626-631.
- HILDRUM H., KRISTOFFERSEN T.1969.The effect of temperature and light intensity on flowering of Saintpaulia ionantha Wendl. Acta Horticulturae 14, 249-255.
- HILLMAN W.S.1956. Injury of tomato plants by continuous light and unfavorable photoperiodic cycles.Amer.J.Bot.43, 89-96.
- HUGHES A.P., COCKSHULL K.E.1971. A comparison of diurnal variation in light intensity with constant light intensity on growth of Chrysanthemum morifolium co.Bright Golden Anne.Ann.Bot.35, 927-932.
- IDLE B.B.1965. A controlled environment room for exploration of the thermal radiation balance between plant and environment.Ann.Bot .(London) 29, 717-723.
- KNAPP R.1956. Untersuchungen aber die Wirkungen taglicher Temperaturschwankungen auf Wachstum, Blatenentwicklung und Fertilitat.Ber.Dt.Bot.Ges.69, 399-412.
- KRUG H., WIEBE J.J., JUNGK A.1972. Calciummangel an Blumenkohl unter konstanten Klimabedingungen. Z.Pflanzenernahr, Dang, Bodenkde 133, 213-226.
- KRUG H., WIEBE H.J.1972.Klimakammern mit indirekter Solekahlung und Taupunktkaler. Gartbenbauwissenschaft 37, 331-344.
- KRUG H., FOLSTER E.1974. Energiekosteneinsparung durch Temperaturfahung.Der Erwerbsgartner 50, 1903-1906.
- MAYER A.M., ADJEKOFF-MAYBER A.1963.The germination of seeds.Pergamon Press, Oxford, London, New York, Paris.
- NEUBAUER L.W.ZSCHEILE F.P.1966.Rotating solatron receives more sunlight for plant growth.Calif.Agric.20, 4-5.
- ORCHARD B.1967. A radiation cooled growth chamber.J.agric.Engng Res.12, 61-65.
- RAPER C.D., SMITH W.T., DOWNS R.J.1973.Growth responses of tobacco to light schedules in controlled environment rooms. Paper NO.73-4526 Amer.Soc.Agric.Engng, Ann. Meeting.Cit.from Downs and Hellmers 1975.
- REICHART G.1965. Ein neues Klein-Phytotron.Angew Bot.38, 276-295.

- SANDVED G.1974.Effect of ulike temperaturer i vintertiden på tilveksten hos noen deokasjongsplanter. Gartneryrket 64, 571-576.
- THOMPSON P.A.1974. Germination of celery (*Apium graveolens* L), in response to fluctuating temperatures.J.exper.Bot.25, 156-163.
- VERKERK K., SPITTERS C.J.Th.1973.Effects of light and temperature on lettuce seedlings. Netherlands J.Agric.Sci.21, 102-109.
- WENT F.W.1957.The experimental control of plant growth.Ronald Press Comp.New York.
- WENT F.W.1961. Temperature.In Handbuch Pflanzenphysiologie 16, 1-23, Springer Verlag Berlin, Göttingen, Heidelberg.
- WIEBE H.J.1974.Zur Bedeutung des Temperaturverlaufes und der Lichtintensität auf den Vernalisationseffekt bei Blumenkohl. Gartenbauwissenschaft 39, 1-7.
- WIEBE H.J., LORENZ H.P.1977. Wirkung von Wechseltemperatur und lichtabhängiger Temperaturregelung auf das Wachstum von Kopfsalat.Gartenbauwissenschaft 42, 42-45.
- YAMAMOTO T., SAKURATANI T.1975. Seasonal change of the plant growth in the artificial light room of a phytotron.In Phytotronics III, 165-172, [ed.by](#) P.Chouard and N.de Bilderling, Bordas, Paris, Bruxelles, Montreal.

x

x

x

XIV. POTATO TUBERIZATION STUDIES IN CONTROLLED ENVIRONMENTS

P.S.HAMMES, Department of Plant Production University of Pretoria, Pretoria 0002 Republic of South Africa

Introduction

During the past seven years numerous experiments in the field of crop physiology were conducted in the phytotron on the experimental farm of the University of Pretoria. In this contribution some of the results obtained in potato tuberization studies will be discussed briefly to illustrate the importance of controlled environmental facilities in agronomic research.

With the exception of Up-to-date, all the potato cultivars of importance in South Africa were locally bred. Very little information regarding the photoperiodic and temperature reactions of these cultivars were available. Such information is especially important in South Africa where potatoes are produced in one region or another right through the year. The natural photoperiod ranges from 11 to 15 hours. Very often potatoes are produced in regions where growing temperatures are much higher than those traditionally associated with potato production.

Procedure

The experiments referred to in this contribution were conducted in PGW36 "Controlled Environments" plant growth chambers. These chambers provided adequate control over light and temperature conditions for the experimental purposes, and are very reliable. The light intensity was approximately 450 me/m²/s measured with a quantum sensor, while the humidity was maintained at + 75%.

Plants were grown in containers filled with clean quartz sand, and watered daily with the nutrient solution used in the Gif phytotron (according to NITSCH (1972)). The sand medium was washed once a week with a large volume of deionised water. Isolated buds (eyes) of potato tubers were used for propagation purposes to obtain uniform, single stemmed plants. This procedure resulted in healthy normal plants. Where less vegetative growth was required the frequency of watering with nutrient solution was diminished. Plants were kept under non-inductive long-day conditions before and after the photoperiodic treatment periods. Throughout the study differences in total radiation between the various treatments were minimized by adjusting the light intensity.

Results

Photoperiod

Tuberization of all cultivars was enhanced by short photoperiods. Even when the dark period was interrupted by only 30 minutes of light initiation of tubers was delayed. One inductive short-day cycle resulted in tuberization under long-day conditions, and a treatment period of ten inductive cycles was adequate for experimental purposes. By subjecting plants of various cultivars to photoperiods of 10, 12, 14 and 16 hours, it was observed that the critical photoperiod was between 12 and 14 hours in all cases. In a subsequent experiment the critical daylength of Up-to-date was shown to be approximately 12 1/2 hours, under the specific experimental conditions.

Up-to-date plants were found to be sensitive to induction soon after emergence, and tubers induced by photoperiodic means were observed as early as 25 days after emergence. However, the plants eventually lost their sensitivity to daylength, and initiated tubers even under long-day conditions after 80 or 90 days.

To determine the effect of photoperiod on growth and final yield, the photoperiodic treatments were maintained for the entire growing period. By exposing plants to different combinations of 9, 12 and 15 hour photoperiods it was possible to study the effects of short days, long days, increasing and decreasing daylengths. Long days (15 hours) resulted in the development of much longer stems, more (but smaller) leaves, longer stolons and better developed root systems than short days. Differences in the final yield of tubers were small, although the yield from plants grown under long-day conditions was somewhat higher. Early in the growing period, though, much higher tuber yields were obtained from plants under short day conditions. The early cultivar Vanderplank was much less affected by the photoperiodic treatments than the others. It initiated tubers earlier under long day conditions (40 days compared to the 70 to 90 days of the medium late cultivars), and did not produce such excessive haulms and stolons under these conditions. Medium late cultivars such as Up-to-date and BPi showed a similar developmental pattern as Vanderplank in short days, but were much more affected by long day conditions, exhibiting delayed tuber initiation

and a lot of stem, leaf and stolon growth. The reaction of the cultivar R100 was intermediate between those of Vanderplank and BPi.

Temperature

In one of the typical temperature experiments the cultivars Up-to-date, BPi and Vanderplank were grown under non inductive 14-hour photoperiods in three temperature regimes, namely 30/20 C, 25/15 C and 20/10 C, on a 12 hour 12 hour basis. Plants were harvested at 40, 80 and 130 days after emergence.

In fig.1 the tuber yield of the cultivars Up-to-date and Vanderplank is illustrated. Tuber yield of BPi was similar to that of Up-to-date, but was omitted from the graph for the sake of clarity. As can be seen from Fig.1, tuber yield was greatly affected by temperature conditions. High yields were obtained at 20/10°C, relatively low yields were obtained at 25/15 C, while at 30/20 C the plants produced almost no tubers, even at maturity. At the first harvest (40 days after emergence), the early cultivar Vanderplank yielded better than Up-to-date at 20/10°C. However, the final

yield of Up-to-date was much better at this temperature. At the higher growing temperature of 25/15°C Vanderplank yielded better than Up-to-date. A significant cultivar x temperature interaction showed that Vanderplank was less adversely affected by higher growing temperatures than Up-to-date and BPi.

The average dry mass of the leaves, stems and roots are presented in table 1. As can be seen from the data the smallest leaf mass occurred at the lowest growing temperature for all the cultivars, yet these plants gave the highest tuber yields. Dry matter production was clearly much more effective at the relative cool temperature of 20/10°C. The larger leaf mass at the higher growing temperatures was the result of a larger number of leaves, though the leaves were generally smaller. The cultivar Vanderplank for instance, averaged 35 leaves per plant at 20/10°C after 40 days, while plants grown at 30/20°C had more than 120 leaves, due to vigorous stem growth and branching. The cultivar BP, normally produced the largest leaf mass, followed by Up-to-date and then Vanderplank.

Stem and root growth showed a similar pattern than leaf mass, increasing significantly when the growing temperature increased from 20/10°C to 25/15°C. At 30/20°C less stem and root growth occurred than at 25/15°C.

Discussion

The growth chamber studies have led to a good understanding of the effect of light and temperature on the growth and development of local potato cultivars. These experiments are being continued with special attention being paid to photoperiod-temperature intercalations, and to the effect of the root and tuber medium temperature on growth and yield.

Although this type of research is rather basic, the information is valuable for the breeder as well as the potato farmer. It will enable the farmer to decide which cultivar should be planted during which time of the year to ensure either maximum yields or maximum income by producing when market prices are high.

References

NITSCH J.P.1972. Phytotrons: Past achievements and future needs. In: Crop processes in controlled environments, edited by A.R.Rees, K.E.Cockshull, D.W.Hand and R.G.Hurd.

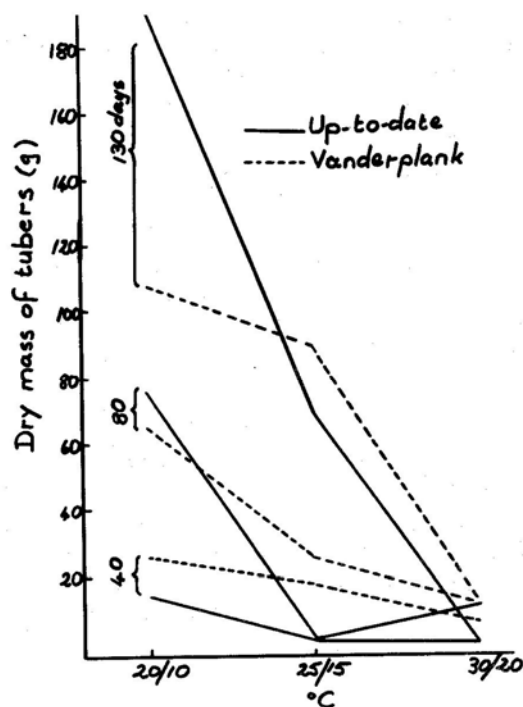


Fig.1-Effect of temperature on tuber mass

TABLE I. Effect of growing temperature on the growth and development of three potato cultivars.

Cultivar Temperature		Average dry mass per plant of					
		Leaves		Stems		Roots	
		40 days	80 days	40 days	80 days	40 days	80 days
	°C	g	g	g	g	g	g
Up-to-date	20/10	14	32	10	38	4,0	5,6
	25/15	21	34	19	56	6,4	14,6
	30/20	13	31	14	49	5,1	12,1
BP ₁	20/10	14	31	11	38	4,6	9,3
	25/15	18	85	18	54	5,7	16,4
	30/20	16	52	17	56	6,7	11,2
Vanderplank	20/10	9	18	5	27	1,7	11,2
	25/15	15	17	15	34	3,7	5,8
	30/20	15	26	15	39	4,8	8,7
LSD _T (p=0,05) CultxTemp		4,5	NS	4,8	28	3,2	6,2

x

x

x

I XV. LIFE HISTORY STUDIES AS RELATED TO WEED CONTROL IN THE
NORTHEAST N° 8 COMMON RAGWEED

Northeast Regional Publication (USA)

Editorial Note. Official Report N° 1033 of January 1978 under the authorship of several University professors is devoted to Ambrosia. We are reprinting several pages of this report relating to problems of photoperiodism and lighting for this weed in a controlled environment. Readers desiring this report should write to Cornell University, Ithaca, NY 14850, USA.

GROWTH AND DEVELOPMENT

The objectives of the experiments and observations presented in this section were to define some of the environmental factors that influence the growth and development of common ragweed, to evaluate its competitive ability, and to determine the differences and similarities between populations of common ragweed collected from diverse locations.

Each plant species has environmental requirements that must be met, or it will not survive. When these are in the best balance, luxuriant growth occurs and seeds form abundantly. Often one can make guesses about requirements of a particular species by observing where it occurs. Obviously, if a species appears at a given site for several years, at least its minimum requirements are being met. On the other hand, just because a species grows in a particular place does not necessarily mean that it is the ideal location. Perhaps growth would be better elsewhere, but other, more competitive species may already occupy that site. Thus, one must not assume that locations given in certain data are the sites that provide the ideal conditions for all the species found in them.

Surveys show that ragweed is often located on roadsides, spoil banks, and well-worn playgrounds, as well as among field crops and vegetables. Obviously, great differences exist between these locations with regard to such factors as soil aeration, nutrient level, and moisture content. In fact, the differences are great enough for us to conclude that ragweed can survive over a wide range of soil conditions.

Date of Planting

Although the germination studies reported earlier indicated that most common ragweed seedlings start early, nonetheless a few do continue to emerge throughout the growing season. DICKERSON (1968) conducted several experiments on the dates when ragweed seeds in the field. He wanted to determine whether late and early emerging seedlings produce similar plants. This work was conducted near Ithaca and Riverhead, New York, locations about 250 miles apart but at similar latitudes. Detailed measurements were made on plants during the growing season as well as at harvest time in September. As a means of showing relative reproductive development, he devised the following rating scale:

- 0= no visible staminate or pistillate inflorescences
- 5= visible, but nondehiscing staminate heads on 75% of the branches
- 5= visible florets without seed in 75% of the axils
- 10= staminate inflorescences on nearly all branches
- 10= florets with **seed** in nearly all axils.

Since the results from the various experiments on planting dates were remarkably similar, only one test- on a sandy soil in Ithaca in 1967- will be reported (Table 6).

This work clearly indicates that when common ragweed is planted to emerge late in the growing season, the plants are small. Thus, under natural conditions, it is fairly certain that ragweed plants which sprout early and escape control will be relatively large at harvest time, whereas those that emerge late are almost certain to be much smaller. However, as Table 6 shows, even these small plants produce more than 3000 seeds each, which, while only 10 percent of the quantity produced by large plants, is sufficient to cause severe infestations.

Light

Photoperiod. The above studies strongly imply that common ragweed is sensitive to photoperiod- a finding in agreement with early work by GARNER and ALLARD (1920) and ALLARD (1943, 1945). Also, SALISBURY (1963) classed common ragweed as a quantitative short day plant, that is, one that flowers earlier under short days than most plants do. DICKERSON (1968) studied certain aspects of photoperiod both in the field and in the greenhouse. In field experiments, he exposed the plants to 30 or 75 minutes of light during the night by means of frosted incandescent 100 watts bulbs which produced at least 52 footcandles at the upper part of the plant. Light-interruption treatments were started in late July and early August and continued until harvest in late September or early October. The data are presented in Table 7.

TABLE 6. Growth and development of common ragweed at Ithaca in 1967,
as influenced by date of planting

Parameter observed					
Planting date	Height	Spread	Fresh weight	Dry weight	Fr.wt/ dry wt.
	cm	cm	g	g	
May 12	97.8	134.8	1,075.0	329.4	3.30
May 29	85.6	115.5	751.8	234.1	3.15
June 9	83.6	107.9	564.6	180.3	3.06
June 23	66.6	76.8	241.2	76.0	3.12
July 8	50.4	48.8	94.7	28.2	3.34
LSD 05	10.5	16.9	269.2	81.1	0.24
0.1	14.8	23.7	377.5	113.6	NS
	Primary branches	Stamin + inflor.	Pistil + inflor.	Seeds/ plant	
	cm	rating	rating	n0	
May 12	30.3	10.0	10.0	32.485	
May 26	28.1	10.0	10.0	15.373	
June 9	28.4	10.0	10.0	8.828	
June 23	23.3	10.0	10.0	5.818	
July 8	18.8	10.0	10.0	3.135	
LSD 05	3.9	NS	NS	15.533	
0.1	5.4	NS	NS	21.778	

+ See scale at top of page 9 for explanation.

TABLE 7. Response of common ragweed to light interruption of the dark
period.

Parameter observed	Normal day length	Night interruption	LSD	
			.05	.01
		8.00 P.M. to 9.15 P.M. (1966)		
Height (cm)	89.8	98.3	NS	NS
Spread (cm)	106.1	109.0	NS	NS
Fr.weight (g)	527.7	910.6	98.4	227.1
Dry weight (g)	144.7	183.0	22.5	NS
Fr.wt./dry wt.	3.7	5.3	-	-
Stamin inflor.+	9.8	3.8	1.8	4.2
Pistil inflor.+	9.3	0.7	2.3	5.3
		12 M to 12:30 A.M. (1967)		
Height (cm)	84.1	92.4	NS	NS
Spread (cm)	124.8	133.2	NS	NS
Fr.weight (g)	1308.6	2070.5	NS	NS
Dry weight (g)	317.4	489.9	NS	NS
Fr.wt./dry wt.	3.5	4.2	NS	NS
Stamin inflor.+	10.0	8.8	+	+
Pistil inflor.+	10.0	8.6	NS	NS

+ See text p.93 for explanation of scale.

+ Experimental error is zero; therefore differences are highly significant, of
questionable practicality. but

Table 7 shows that the relatively long period of light interruption (1 hr 15 min) in 1966 resulted in substantial increases in fresh weight of plants and significant reduction in lowering. However, the 30 minute light interruption in 1967 showed little significant difference. The large numerical difference in fresh weight was not significant in 1967 because the variability coefficient then was 29 percent, whereas in 1966 it was only 13 percent.

In greenhouse studies, DICKERSON (1968) obtained additional evidence of ragweed response to a 30 minute interruption of the dark period by 30 footcandles of light from incandescent lamps. He further showed that flowering could be initiated with long days, 16.25 hours, but that it took much longer than with shorter days. He therefore concluded that SALISBURY'S classification (1963) of common ragweed as a quantitative short day plant was correct.

Light Intensity. This factor could play a role in survival or competitive ability of a plant species. In noncrop situations, common ragweed is often the only species present in significant numbers. However, in row crops and small grains, common ragweed coexists with the agricultural crop, along with other weed species. Shade from another plant species may influence the growth and development of common ragweed.

DICKERSON (1968) investigated this aspect under field conditions in several experiments. A shade cloth was laid over structures built of posts and wires to reduce sunlight either 30 or 73 percent. These shade structures were at two locations (01 sandy loam and silt loam soils) and were of a size and height that permitted soil preparation by tractor. In some instances, plants were grown in large pots, so that water use and mineral nutrition could be controlled.

In an experiment on silt loam soil, seedling ragweed was transplanted at 30 days of age to 0, 30% and 73% shade. Some of the data obtained are presented in Table 8, ,

It is readily apparent that ragweed is not harmed by moderate shade; in fact, both fresh and dry weight may be increased by moderate shade.

TABLE 8. Response of common ragweed to 3 levels of shade
+ See text p43 for explanation of scale

Shade	Height	Spread	Fresh weight	Dry weight	Staminate inflor.	Pistillate + inflor.
	CM	cm	g	g		
None	74.6	78.1	268	77	10.0	8.5
30%	77.9	79.2	300	81 ^{xx}	9.7	7.3
73%	70.8	69.5	147 ^{xx}	38	9.9	8.4
	NS	NS	99.1	99.1	NS	NS

xx Significant at 0.1

In view of these results a more elaborate experiment was conducted with ragweed, sweet corn, and dry beans planted separately in pots and placed under similar levels of shade after 30 days. Some of the data obtained are presented in Table 9. It is again apparent that ragweed is not adversely affected by 30% shade, but rather, dry weight was actually increased. In Table 8, the data were obtained from plants watered only moderately by overhead irrigation. However, the data in Table 9 were obtained from pots with plants that were watered individually only when they wilted slightly. The authors are reluctant at this point to ascribe the response of ragweed to shade as a function of moisture and stomatal behavior. If this were so, beans and corn should also perform better under partial shade, but they did not. We believe that ragweed has some other efficiency factor that permits it to produce more dry matter under partial shade. Similar stimulation from 25% shade was reported

with barnyardgrass (*Echinochloa crusgalli*) by DICKERSON (1964); from 33% shade with wild radish (*Raphanus raphanistrum*) by RAHN and FEULNER 1968; from 25% shade with common purslane (*Portulaca oleracea*) by VENGRIS and LVINGSTON (1968).

Light Quality. DUNN studied this factor in New Hampshire. He worked with fluorescent lamps of 5 colors adjusted to provide an intensity of 800 , uW cm² at plant level. The light qualities of each lamp have been described in detail (DUNN et al. 1968). He

worked in air conditioned growth chambers maintained at 21 C for a 16-hour light period and at 1efor an 8-hour dark period. Several experiments were conducted under these conditions, and some of his data are presented in Table 10. He remarked on a good deal of variability among his plants, even though seed was obtained at only one site. He suggested that wide range of genetic variability probably exists. Similar observations by DICKERSON (1968) were mentioned in an earlier section. The effects of light quality were significant for dry weight only. Red light was superior to green and blue, and white and yellow were intermediate. DUNN summarized his study on light quality with common ragweed by stating that this species responded similarly to barnyardgrass (*Echinochloa crusgalli* L.) and crabgrass (*Digitaria sanguinalis* L.) as reported previously (DUNN et al. 1968).

TABLE 9. Influence of shade on growth of common ragweed, dry beans, and sweet corn

Crop	Shade	Height	Spread	Fresh weight	Dry weight
		cm	cm	g	g
Radweed	None	62.4	67.9	201	45.8
	30%	66.7	76.2	275	54.3
	73%	45.5	53.7	104	21.2
Dry beans	None	42.1	44.7	209	40.2
	30%	42.8	46.9	212	37.4
	73%	42.6	47.5	154	22.9
Sweet corn	None	126.3	16.9	421	81.1
	30%	133.8	13.5	419	75.2
	73%	116.0	9.3	281	44.2

TABLE 10. Response of common ragweed to 5 different light qualities +

Plant character	Red	White	Yellow	Green	Blue
No. days for pollen shed	32.0	35.7	42.3	37.4	32.2
Height in cm	26.8	24.4	24.2	21.0	19.5
No. female flowers	27.7	22.6	7.3	10.0	14.7
No. male flowers	9.2	10.3	6.5	6.0	6.6
Fr. wt (g) tops + roots	61.8	47.7	48.9	42.3	31.3
Dry wt (g) tops + roots	9.3a	6.9a b	6.6a b	5.6b	4.1b

NOTE: Values in same line having same letter are not different at 5% significance level.

+ See DUNN et al. (1968) for detailed description of light quality.

XVI. HYDRAULIC ARCHITECTURE OF TREES

Editorial Note. In April 1977 during his stay in France, Professor ZIMMERMANN held a conference on this subject at the Phytotron in Gif-sur-Yvette. Given its originality, we are publishing a short summary of this conference and advise those interested in this problem to write to the eminent Professor: Dr. M. H. ZIMMERMANN, Harvard University, Harvard Forest, Petersham, MA 01366 USA.

In his notes about painting trees, LEONARDO da VINCI wrote that the body of a tree stem is equal to that of the branches, just as branches of a river are equal to the main body of the river, provided velocities are the same. Early during this century botanists investigated this quantitatively. For example, HUBER (1928) described the situation by expressing the transverse-sectional area of xylem of stem (or branch) per fresh weight of leaves supplied by that axis. He found fairly uniform values, namely between 0.5 and 1 mm²/g. This number increased sharply to about 4 towards the leading shoot of a small fir tree (*Abies*) and HUBER interpreted this as an expression of apical dominance (see fig.1).

There are two major reasons why transverse sectional area of xylem is a poor measure for the capacity of xylem to conduct. First, we do not know how much of the xylem transverse sectional area is really conducting, especially in older trees. Second, and more important, the volume of liquid moving in capillaries is proportional to the fourth power of the capillary radius. This means that when capillary diameter is increased 10%, conductivity increases 50%, if the diameter is increased four-fold, conductivity increases 256-fold.

We looked at the hydraulic construction of trees by measuring microliters of water flowing through sections of stem, per hour, under conditions of gravity flow, per gram fresh weight of leaves supplied by the measured stem section. Fresh weight of leaves is the simplest measure of transpiration requirement, considering that we were dealing with sizable trees and thus with thousands, tens or hundreds of thousands of leaves. We call this measure "leaf specific conductivity".

Trees were cut in the forest, immediately put into a bucket or plastic bag with water, and carried to the laboratory. While still in water, they were defoliated and the leaves above each check point weighed, and the stem sections were cut from the tree. These over length pieces of wood were soaked in water to relax the tension in the xylem. Pieces to be measured were cut to a length of about 15 cm, the end surfaces trimmed cleanly with a razor blade or microtome knife, and briefly vacuum infiltrated to prevent embolism of the cut vessels. Flow rate enough the pieces was measured either by having water run through from a pipet by gravity flow, or in the case of larger pieces, having the water drip into a container on a balance. Leaf specific conductivity was then calculated (fig.2).

Two complications arose, both could be avoided, but the nature of them is not yet understood. First, there seems to be an end effect. The ends of the piece have a resistance to flow about equal to 2.5 cm additional stem length. We used uniform lengths of pieces and ignored this phenomenon. Second, flow rates of distilled water are not constant, but decrease continuously with time. This had earlier been ascribed to tiny air bubbles or dirt particles lodging against vessel to vessel pits, because reversal of the flow direction restores the initial flow rate. We found, however, that this phenomenon could be completely eliminated by using a very dilute salt solution. Indeed the flow rate of 5mM KCl is often considerably greater than the initial flow rate of distilled water, and it is constant. This is probably an electrical phenomenon which we do not understand at the moment. In all experiments we used 5 mM KCl.

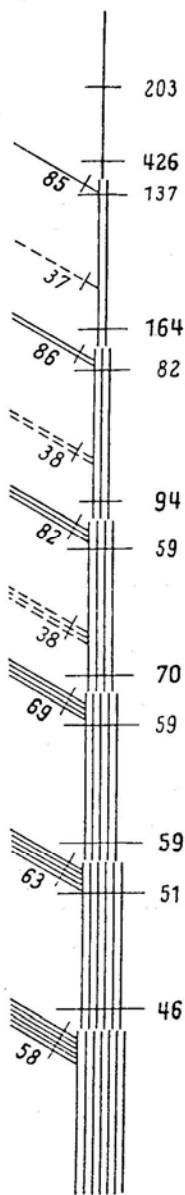


Fig. 1. Numbers are transverse-sectional areas of xylem in one hundreds of square millimeters of stem and branches per gram of fresh weight of leaves supplied in *Abies concolor*. From Huber, B. 1928. Jahrb. wiss. Bot. 67: 877-959.

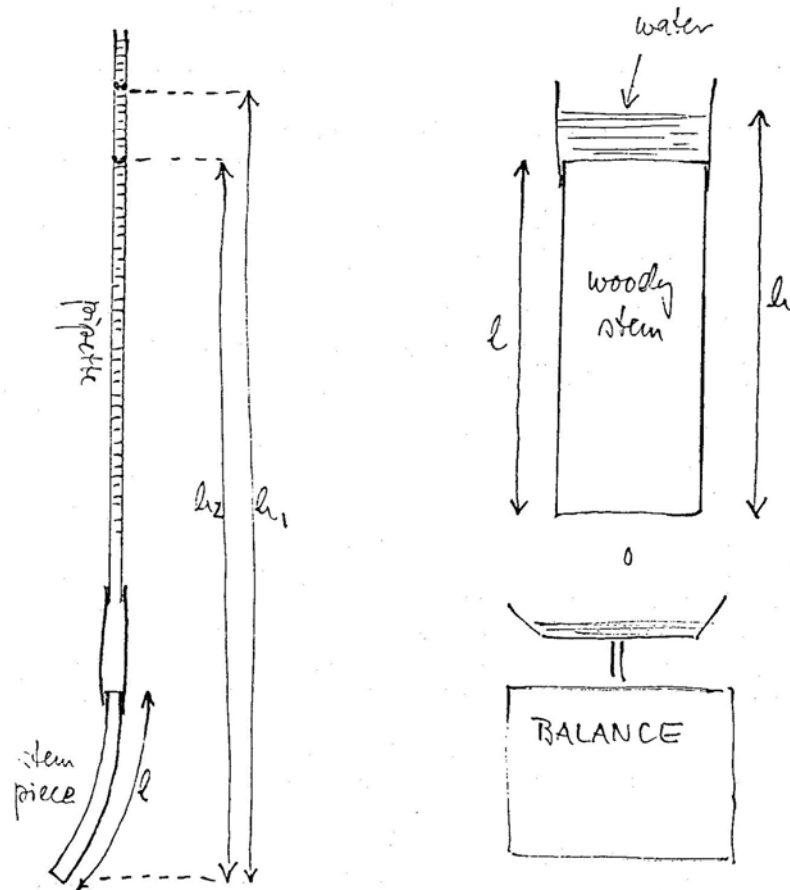


Fig. 2. Measurement of leaf specific conductivity of xylem (LSC). The rate of water flow through the piece of stem is measured as flow from a pipet or, in larger stems, flow onto a balance. Flow rate is calculated per hour and under conditions of gravity flow, i.e. flow rate divided by $(h_2 + h_1)/2$ and multiplied by the stem length l . This value is then divided by the fresh weight of all leaves that are supplied via the stem section.

Figure 3 shows some results. In all cases we found that the leaf specific conductivity (LSC) is greater along the main stem than along branches. In Populus grandidentata and Betula papyrifera LSC in the stem are 250 to 300 at the base of the tree and decrease slightly in apical direction. LSC in branches are about one fourth to one half that of stem values. In Acer saccharum LSC increase in distal direction in the stem. The most interesting result is the fact that all junctions, stem to branch or branch to twig, represent hydraulic bottle necks. Recent very detailed anatomical investigations of LARSON indicate that there are hydraulic restriction also from twig to petiole.

The reciprocal value of the square root of LSC (we use $100/\sqrt{\text{LSC}}$) is proportional to flow velocity, assuming that all leaves transpire equally. Flow velocities are greatest at branch insertions, this means that there is a sharp pressure drop across each junction.

Physiologists have often wondered how trees can enable the leaves at the top of the crown to compete successfully for water with the leaves positioned near the bottom of the tree in spite of the fact that for hydrostatic reasons the top leaves are disadvantaged. The hydraulically segmented construction of trees described above explains the phenomenon rather simply. Under conditions of flow, the constriction caused pressure drop across each junction induces the lower leaves to close their stomata more quickly than the leaves at the top of the tree which obtain their water via a straight stem path. The succession of pressure drops insures that the lowest pressures are always in leaves, and the highest ones in the stem. If tensions are great enough for embolism to occur during drought, embolism will first occur in leaves, then in outer twigs. The stem will survive best.

When pressure gradients were measured along stems of tall trees, they were often found to be less than hydrostatic under transpirational conditions (SCHOLANDER et al. 1965, TOBIESSEN et al. 1971, see fig. 4). As a result of this puzzling finding either the pressure bomb method of measuring xylem tensions, or the cohesion theory of sap ascent was questioned. Our LSC work explains these gradients easily: pressures at the tips of transpiring branches must be much lower than pressures in the stem at the same height. To measure stem pressures, it is necessary to prevent transpiration in the whole branch on which measurements are made.

We investigated the nature of hydraulic constrictions at junctions, and the nature of lower conductivity in branches. When two different dyes are let to flow downward through the two branches of a Y-shaped junction, one can measure the amount of xylem belonging to each of the branches. This simple procedure indicated that the xylem area is restricted via the angled portion of the axis. It is not restricted, or only slightly restricted in the straight portion. We furthermore discovered that the diameter of stem vessels "belonging" to a lateral branch are slightly, but statistically significantly narrower than those belonging to the straight portion of the stem. We believe this to be the phenomenon that has been described by plant anatomists a long time ago: vessel diameter increases with distance from the leaves. It explains the lower conductivity of lateral branches.

In summary we can say that the hydraulic architecture of trees is ideal for survival, it insures the safety of the main stem and causes the sacrifice of laterals under conditions of extreme stress.

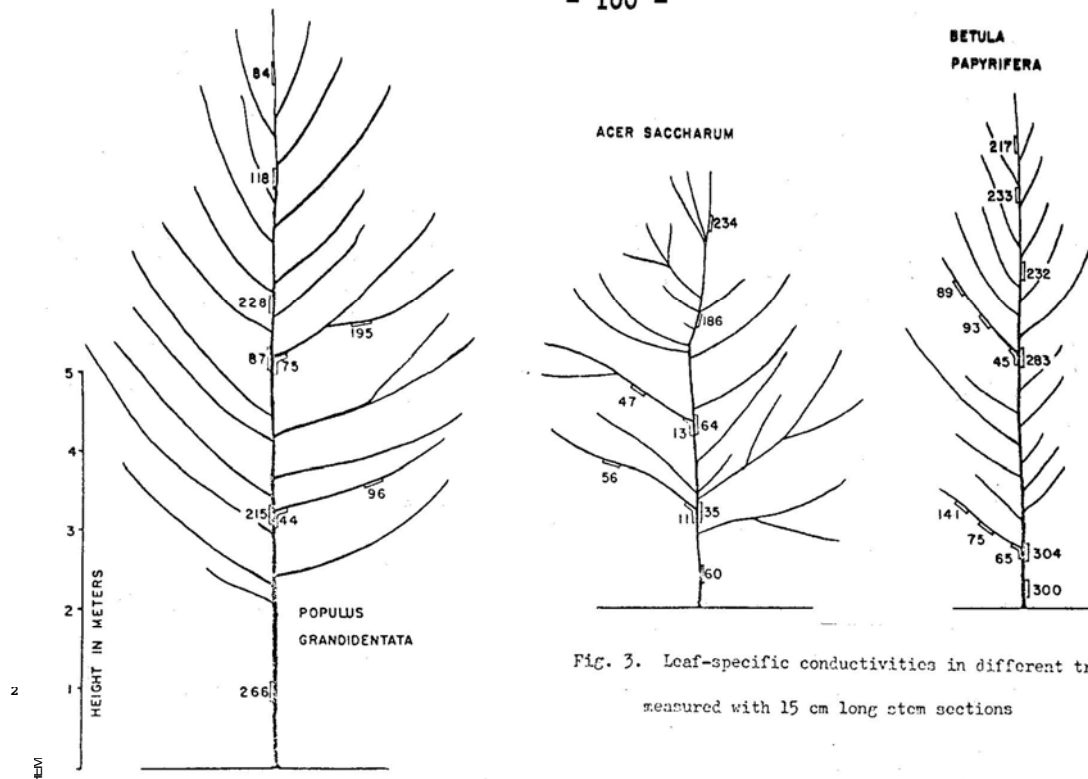


Fig. 3. Leaf-specific conductivities in different trees, measured with 15 cm long stem sections

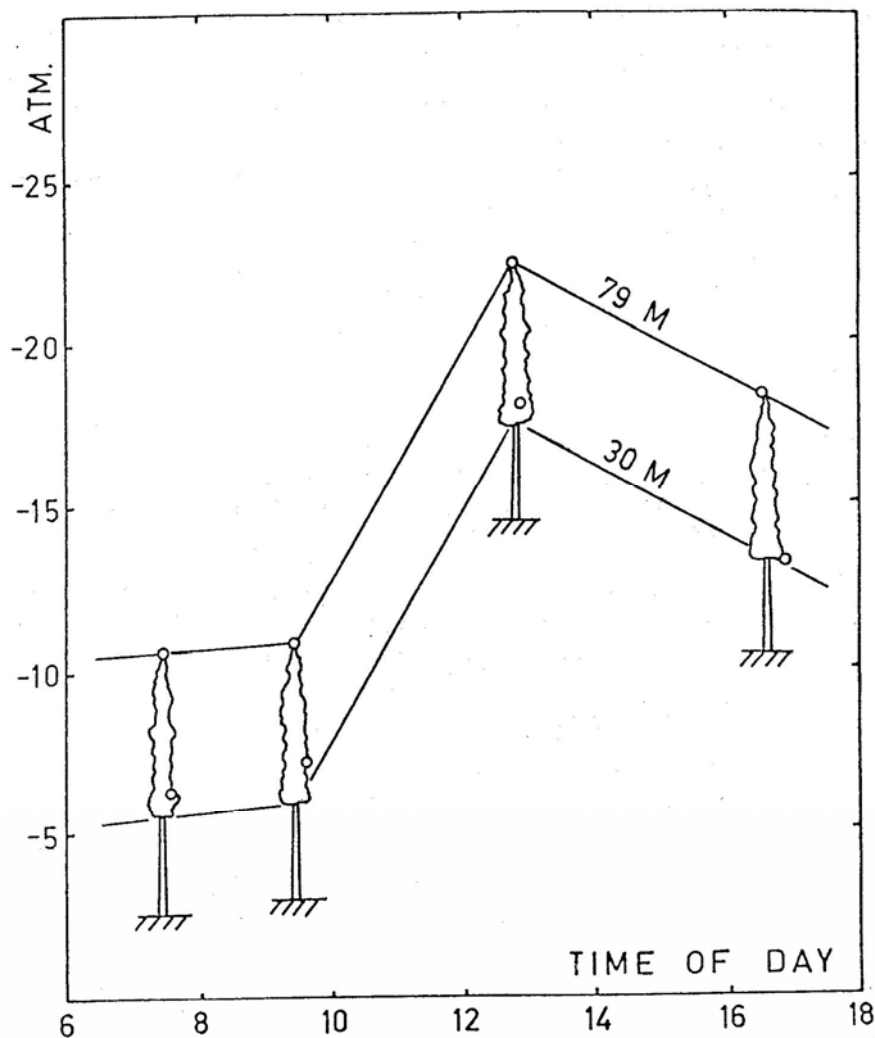


Fig. 4. Tension gradients in a tall Douglas fir. Note that the gradients are less than 0.1 atm./m. From Scholander et al. (1965. Science 148: 339-346).

CONTAMINANTS IN PLANT GROWTH CHAMBERS

Growth chamber Committee. American Society for Horticultural Science

Editorial Note. This study, published in Hort. Science (vol. 12 (4) August 1977, p. 310-311) was sent to us by the President of the Committee. Many important ideas in this study make publication here worthwhile.

Introduction. The Growth Chamber Committee of the Society held a workshop on August 13, 1976 at Louisiana State University in Baton Rouge, Louisiana at the annual meeting on Contaminants in Growth Chambers. Observations and comments present at the discussion are summarized in this report.

Mercury

Contamination of growth chambers by mercury vapors is a serious threat because of the many potential sources of this element. Glass mercury thermometers are primary on the list and should be avoided if possible but used with great caution if other types are not available. Other sources of mercury contamination include broken fluorescent lamps, switches, recording thermometers, water baths, thermostats, antifungicidal paints, and some cleaning compounds. Once mercury contaminates a chamber, it may remain for long periods, primarily because of the difficulty in detecting and removing it.

One participant offered some suggestions in dealing with mercury contamination after breaking a mercury thermometer in a closed chamber. Cleaning included recovery using an eyedropper, vacuuming, and washing with soap and water. It was assumed that the chamber was clean and it was used for the next year without suspecting residual mercury. Contamination was identified when the chamber was being checked out for use in ozone fumigations. A Dasibi ozone monitor recorded a level of 4 ppm ozone although no ozone was present. This instrument detects ozone by UV absorption; however, mercury also absorbs UV light and is 80 times as sensitive to mercury as to ozone. A quick calculation indicated that this monitor is capable of detecting a minimum concentration of 12 ppb mercury in air and therefore, can be utilized effectively for detecting mercury contamination in growth chambers. Additional chamber clean up with vacuum and soap and water was of very little value. An acid rinse reduced the mercury concentrations but residues persisted. Washing with a solution of sodium sulfide reduced the mercury to about one fourth its original concentration. The spill site was next dusted with sodium sulfite crystals and the chamber closed for 24 hours. The crystals were then removed by suction and the area rinsed with water. This procedure successfully eliminated mercury from the chamber atmosphere as determined by the ozone monitor. Sugar beets and roses were suggested as being sensitive bioassays for the identification of mercury contamination.

Paints

Some paints release toxic materials upon drying. Problems have been most acute with rust resistant paints applied to radiators or heating pipes. The solvent, xylene, has been identified as damaging to cultivars of chrysanthemums. Paints are not only a problem when sprayed in a chamber but also when used any place in the building. One participant reported having trouble growing cotton and peanut plants for about 2 months after refurbishing a chamber with white epoxy paint. Chamber users often have no control over the practices of maintenance personnel outside of the chambers; thus the complete elimination of these types of problems is impossible. However,

awareness of potential problems may allow the selection of paints with non toxic carriers and drying agents. A recent article on phytotoxic paints in Florists' Review may be helpful. (Seely J.G.1976. Some paints can cause plant injury. Flor.Rev. 158 (4103) 65, 117-119).

Ideally, growth chambers should be maintained in an area where a separate air source supplies all chambers. This should be independent of influences such as heating plants, chemistry labs, and other potential polluters. This would also allow control of paint fumes to times and sites that do not interfere with investigations underway.

Plastics

Plastic screening was used by one participant in a chamber to adjust light intensity. He observed that a marginal chlorosis developed on the tip of the first true leaves of mung bean plants when a bonded type of screening was used but did not have problems with unbonded screen. The identity of the compound was not verified but the bonding material contained diethylphthalate, dioctyl-fumurate, and 2-hydroxy, 4-oxo-2,2-diphenylpropan-1-one. Plasticisers containing chlorine were also reported as being a source of problems.

A discussion of problems encountered when using sealants revealed the following ideas. Silicone sealant comes in many forms with some satisfactory for chamber use while others are not. Problems generally involve the length of curing time and volatile compounds released during curing. When applied in a thick layer or as a plug, the curing can be prolonged for many weeks. Polysulfide sealers were suggested as being easier to sterilize and faster curing.

Ethylene

In sealed chambers some species are damaged by exposure to ethylene produced by the plants themselves. One participant reported that cotton plants generated enough ethylene to cause severe epinasty of the cotyledons. Plastics are also suspected of producing ethylene in closed chamber work. The ultraviolet radiation produced by fluorescent lamps may degrade polyethylene to release ethylene. Plastics should, therefore, be used with caution in closed chambers. When sufficient air exchange is provided in growth chambers, ethylene problems are usually not evident.

Cleaning agents

Bacteriocides and algicides often leave residues which may volatilize, especially in sealed chambers. Caution was stressed in selecting and using cleaning agents. One participant commented on his experience in trying to sterilize a hydroponic system contained within a walk in growth chamber. After washing with a detergent and rinsing, the system was filled with a sodium hypochlorite solution. After draining, it was next filled with dilute nitric acid. This resulted in the generation of chlorine gas which destroyed an experiment in an adjacent chamber and nearly injured the investigator.

Chamber cleanliness was stressed and the use of glassware detergents, such as Alconox or Labco, was suggested. Chlorox and alcohol were suggested as appropriate disinfectants, if proper attention is given to the removal of volatiles released during drying.

Steam additives

Many growth chambers utilize steam from a building heating system for humidification. In most cases, anti-corrosion compounds are added to prevent the return steam lines from becoming clogged with algae, bacteria and fungi; and these compounds have been found to cause injury to plants. The additives are general biocides such as cyclohexylamine, morpholine, and octadecylamine. One participant reported damage to plants from this steam. Soil sterilized with steam may also be contaminated by these compounds and three participants reported they had encountered this problem.

It was reported by one participant that several cultivars of chrysanthemums had been killed by steam additives. It was suggested that to eliminate this source of contaminants, separate steam generators or other types of humidification systems be employed. The need for good quality de-mineralized or distilled water was stressed.

Ultraviolet radiation

One participant reported on the emission of UV radiation from standard fluorescent lamps. The disadvantages or advantages of this small amount of UV radiation are not known. Standard glass or plexiglass barriers between the fluorescent lamps and the growing area will likely reduce plant exposure to the UV radiation.

Phytotoxic gases

One participant reported that every time a compressor was changed or repaired in the growth chamber area, problems were evident on cabbage plants. Symptoms appeared as grayish necrosis of cotyledons, and mottled chlorosis of the first and second true leaves. Welding was suspected of producing phytotoxic gases in the presence of residual amounts of freon for there is published information on the formation of HF and HCl when freon gas contacts a flame or the surface of electrical heaters.

x

x

XVIII. SIMPLIFYING THE LAMP CHANGING SCHEDULE IN PHYTOTRONS
WITH THE HELP OF A COMPUTER PROGRAMME

R.C.HARDWICK and D.J.ANDREWS, National Vegetable Research Station, Wellesbourne, Warwick UK.

In many Phytotrons, the lamps are not installed in a single batch and replaced as a single batch. Instead, a mixture of lamps of different ages is set up. The aim is to maintain a balanced population of lamps and to stabilize the luminous flux output. In practice, this is easy if the lamps are in blocks but if each lamp is individually switched the task of "book keeping" becomes very complicated. In the phytotron facility at the National Vegetable Research Station we now use a computer programme to do the book keeping. The programme has been used continuously for the past four years.

Basically the programme recognises three types of information about a cabinet; that a new experiment has been set up (in which case the programme expects data indicating which lamps have been switched on, and how many hours they run for each day); or that the lamp settings this week are the same as those recorded previously; or that some lamps have been turned off, or on, or exchanged, since the last run of the programme. This information is input to the computer every 7 or 10 days. The programme produces for each cabinet- a message about the number and location of any lamp which has exceeded 7000 hours running time, and a message about the current state of the lamp population. The population is regarded as being divided into several groups (for example 0, 2000, 4000 and 6000 hour nominal age) and the message indicates the true average of each group of lamps, together with a statement drawing attention to any individual lamp which has run 200 hours more, or less than the average of the group as a whole. It is then a simple task for the operator to adjust the lamp switching when the lamps are next trimmed, thereby maintaining a more constant environment for the plants.

The programme is written in FORTRAN IV, and has been designed to be as "robust" and simple to use as possible. Further details are available from NVRs; please quote the name of the programme, which is LAMPCK.

I XIX. CONTROLLED ENVIRONMENTS WORKING CONFERENCE MADISON. UNIVERSITY OF
WISCONSIN, March 12-14 1979

Professor T.W.TIBBITTS sending us following announcement precise:

"Our growth chamber groups here in the United States are planning a Working Conference on Controlled Environments for March of 1979 as outlined in the attached announcement. Because of fund limitations, our programming has been with individuals from America but we would encourage scientists from all countries to attend and participate".

This working conference will identify the critical aspects of controlled environments for plant research and define improvements in techniques for conducting experiments within these facilities. Keynote speakers and invited discussants will detail plant growth requirements, measurement and control of light, temperature, atmospheric moisture, carbon dioxide, nutrition and watering in controlled environments. This will be followed by presentation and open discussion of guidelines for measurement and reporting of the environment.

Sessions are being developed for the presentation of contributed posters and demonstrations on plant requirements, instrumentation and measurement of the environment in chambers. Interested plant physiologists and engineers are invited to participate in poster and demonstration sessions and to share in the discussions.

The working conference is being jointly sponsored by the Biotron of the University of Wisconsin-Madison, the North Central Region Research Committee NCR 101 (SAES-USDA), Environment and Plant Structures Committee SE 303 (Amer.Soc.Agr.eng.) and the Working Group on Growth Chambers and Controlled Environments (Amer.Soc. Hort.Sci.).

Requests for information on registration for the conference should be addressed to T.W.TIBBITTS, Horticulture Department, University of Wisconsin, Madison WI 53706.USA.

x x

x

XX. CLIMATE LABORATORY NEWSLETTER 1

Here we reproduce some informations of n°9 april 1978 of this New Zealand review sending to us by Dr.I.I.WARRINGTON, the editor's (Plant Physiology Division DSIR, Palmerston North-New Zealand).

x

Controlled Environment Room Use

Room use for the 12 month period 1 May 1977 to 1 May 1978, is shown in Table I for each of the main user groups. The DSIR Divisions' projects required more space than that allocated and overall service project room use also exceeded the allocation total. Low room use by the MAF and high use by the DSIR and the Forest Research Institute continue to be a feature of Climate Laboratory use.

Plant Physiology Division's increased use was associated with the presence of several visiting overseas scientists. The Division has also begun a "foreign aid" project with ICRISAT (International Crops Research Institute for the Semi Arid Tropics, Hyderabad, India). The current level of room use by PPD scientists is likely to continue.

The total occupancy of the Laboratory was 91% (89%) and the number of projects handled during the 1977-78 period was 28 (26). The 1976-77 figures are in parenthesis.

Projected room use

Several of the current projects will run through the remainder of this year. There is a major experiment scheduled from FRI on the frost tolerance of Eucalypt species, but room use by the Universities and MAF will be low after April 1978. There is also some unallocated space available for DSIR projects.

In contrast PPD's demand for space over the May-Dec '78 period is high and will equal its allocation.

Publications

The number of scientific papers published each year from climate Laboratory work continues to increase. In 1976 there were 13 papers and in 1977 (to date) 15 papers and 4 theses. There have now been 50 papers and 7 theses published since 1972.

Of the 186 projects completed to date

55 contributed to the 50 papers and 7 theses, results from 61 are with the project originators and will contribute to an estimated 35 to 40 papers, 59 will not be published in any form, and 11 are still in progress.

Since the last Newsletter a paper on the Climate Lab. and Forest Research Institute C.E. facilities' lighting systems has been published and another on the low temperature "frost" rooms have been submitted for publication.

New facilities and equipment

The three 10 x 7 m concrete floored frame houses were completed last May and were intensively used throughout 1977 to house Pinus radiata seedlings used in frost room studies. This year up to 7000 Eucalyptus spp. seedlings will be held in the frames prior to their frosting treatments.

The Nursery Services group now has a small tractor and fork lift which will enable batches of 40-50 plants on pallets to be moved around the research area and to and from the Climate Lab. Previously plants were moved on hand trolleys.

The Biological Services Group has ordered a new spectroradiometer (Optronics model 740A with cosine head) to replace our aged (pre 1967) ISCO model. The instrument will be used to measure spectral quality (e.g. lamp comparison studies, lamp combination work etc.) of light in the controlled environment rooms.

The CO monitoring and injection system is being overhauled and calibrated and the Automated Nutrient System make up facilities will be rebuilt during 1978.

Air Pollution Research

The modification of a reach in cabinet for sulphur dioxide/plant growth studies is expected to be completed by May 1978. A Thermo Electron Corporation pulsed fluorescent SO₂ analyser is being purchased to control and monitor the concentrations of pollutant.

These facilities will be used initially by the Forest Research Institute to investigate the effects of sulphur dioxide on P.radiata growth and development. This research is part of a program to assess the possible effects of SO₂ emission from the proposed Broadlands geothermal power station.

The air pollutant cabinet is available for all for experiments on the same basis as other controlled environment rooms. It will provide SO₂ levels from 0.01 to 10 ppm and will operate over the normal temperature, humidity, irradiance and daylength ranges.

Controlled Environment Cabinet Workshop

A very successful workshop was held on 8-9 june 1977 to instruct technical personnel from around the country on the operation and maintenance of reach in controlled environment cabinets. The two day session included discussions on air conditioning (refrigeration and heating systems), humidifying and dehumidifying systems, lighting technology, electronic controller operation and fault diagnosis. The proceedings have been published and are available on request (Technical Report n°6, june 1977, Plant Physiology Division DSIR, Palmerston North N.Z. 62 pp).

New Projects

N°169. E.T.KANEMASU and al.A study of the leaf and reproductive development of corn (Zea mays) :responses to temperature.

N°170. D.A.ROOK and D.G.HOLDEN.Seasonal patterns of frost tolerance in different radiata pine nursery stock.

N°171.D.G.HOLDEN and D.A.ROOK.Seasonal patterns of frost tolerance of 1/0 and 1 1/2/0 planting stock.

N°172. J.ESSON.Resistance of medic lines to sitona weevil feeding.

N°173.J.de RUTTER and A.D.TAYLOR.Influence of phosphate level on dry matter production of several winter growing annual legumes.

N°174.H.A.EAGLES and A.K.HARDACRE.Genotypic variation in cool tolerance of maize seedlings.

N°175.D.A.ROOK and G.B.SWEET.Comparison of the growth of seedlings and rooted cuttings of Radiata Pine.

N°176. D.A.ROOK.Effects of seedling nutrient status on frost hardiness of Radiata Pine foliar nitrogen sulphur and potassium levels.

N°177.F.L.MILTHORPE.Growth of wheat at low temperatures.

N°178.I.J.WARRINGTON and E.A.EDGE.Plant growth under "stepped" lighting regimes with peak irradiance levels equivalent to "full" sunlight.

N°180.K.H.WIDDUP.Responses of five white clover races to lowered temperature.

N°181.A.T.PUGSLEY and al.Vernalisation and photoperiod responses in Australian and New Zealand wheat cultivars.

N°182.M.BOLAND.Enzymology of nitrogen assimilation.

N°183.T.R.D.FIELD and W.F.HUNT.A comparison of the growth and partitioning of a white clover selected for hill country with several other white clover types.

N°184.D.A.ROOK and D.G.HOLDEN.Variation in frost tolerance of Eucalyptus regnans F. Muell.

^o_N 185.H.A.EAGLES and al.Inheritance of groat protein concentration in crosses between Avena sativa and a strain of A.eterilis of Libyan origin.

^o_N 186.H.G.Mc PHERSON and al.Daylength temperature effects on time to flowering of pigeon pea (Cajanus Cajan)

Scientific publications in 1977

BEARDSLELL M.F.Effects of routine handling of maize growth.Austr.J.Plant Physiology 1977, 4, 857-861.

CHOU C.K.S.Effect of tree age on Diploidia Pinea infection of Pinus radiata.Plant Disease Reporter 1977, 61, 101-103.

CROUDHARY M.A. and BAKER C.J.The interrelationship of direct drilled seeds and dry soils as a function of sowing techniques under controlled climatic conditions. Energy Conservation in Crop Production 1977. Massey Univ.14 pp.

CHU A.C.P. and Mc PHERSON H.G.Sensitivity to desiccation of leaf extension in prairie grass.Aust.J.Plant Physiol.1977, 4, 381-387.

FORDE B.J. and al.Effect of temperature, vapour pressure deficit and irradiance on transpiration rates of maize, paspalum, westerwolds and perennial ryegrasses, peas, white clover and lucerne.Austr.J.Plant Physiol.1977, 4, 889-899.

de RUITER J.M. and TAYLOR A.D.Seedling growth of Medicago truncatula and Ornithopus sativus on a manawater fine sandy loam as affected by pH, N, P, K and rhizobial inoculation.Proc.Agron.Soc. NZ 1977, 7, 51-53.

GADGIL P.D.Duration of leafwetness periods and infeetion of Pinus radiata by Dothistroma pini.N.Z.J.For.Sc.1977, 7, 83-90.

JENKINS P.A. and al.Influence of photoperiod on growth and wood formation of Pinus radiata.N.Z.J.For.Sci.1977, 7 (2), 172-191.

LANCASTER J.E. and all.Effect of age on amount and type of glycoalkaloids in leaves and roots of Solanum laciniatum.N.Z.J.Agric.Res.1977, 20, 395-399.

McPHERSON H.G. and BOYER J.S.Regulation of grain yield by photosynthesis in maize subjected to a water deficiency.Agron.J.1977 69 (4) 714-718.

MOIR K.W.and al.The in vitro digested cell wall and fermentation characteristics of grasses as affected by temperature and humidity during their growth. J.Agric.Sc.Camb.1977, 88, 217-222.

SCOTT R.S.The phosphate nutrition of white clover.Proc.N.Z.Grassland Assn.1977, 38, 151-159.

WARRINGTON I.J.and al.Growth and physiological responses of soybean under various thermoperiods.Aust.J.Plant Physiol.1977, 4, 371-380.

WARRINGTON U.J. and al.Lighting system in major New Zealand Controlled environment facilities. J.Agric.Engng Res.1978, 23(1) 23-36.

University Theses

- BEATSON R.A. Diabolel analysis of varying late season night temperatures on the development of a range of flue cured tobacco (Nicotiana tabacum L.) Genotypes M.Agric. Sc.1977, 132 pp.
- BROOKFIELD P.L.P. Effects of water stress at different stages of growth on seed yield of safflower. M.Agric. Sc. 1977.
- CROSS R.J. Effects of genotype and environment on the sprouting propensity and other grain characteristics of wheat (Triticum aestivum L.) M.Agric. Sc. 1977, 294 pp.
- MARTIN R.J. Some environmental effects on the water status of wheat. Ph.D. Thesis 1977 209 pp.

x

XXI. ESNA. EUROPEAN SOCIETY OF NUCLEAR METHODS IN AGRICULTURE 1

The Secretariat of ESNA has sent us ESNA Newsletter with news from the meeting held in Uppsala (Sweden) on 15 november 1977 by working group Nuclear techniques in the Study of Soil Plant relations.

In the report of the chairman we read:

The Soil Plant relations working group met during the VIII Annual Meeting of ESNA three times and the topics which were discussed are:

- Fate of fertilizer nitrogen in cultivated soils
- Fertilizer efficiency studies
- Measurement of root development by radioactive tracers

There were considerably more participants than last year, the number of lectures increased slightly, the quality of the papers was considerably higher than last year and also the way of presenting of papers (and slides) improved.

The question arises then whether there was also scientific progress. This question can certainly be answered positively. There was a general tendency to study agricultural systems as a whole and there is also a trend to perform long term studies before conclusions are drawn. Some years ago it was still possible to present a lecture based on a few uptake experiments carried out with excised roots, such a thing is now impossible. On the contrary, we are approaching the situation that we can provide more or less complete nutrient balances of particular agricultural systems. This improves our insight considerably. Reason for this development is three-fold:

- In the first place it is without doubt the fact that at present much more sophisticated equipment, nuclear and non nuclear, is available, so that it is possible to determine more factors simultaneously.
- In the second place it is the application of system analysis which promotes the study of agricultural systems as a whole.
- And in the third place must be mentioned, the improved international contacts: Programmes and discussions as organized by the FAO/IAEA joint division in Vienna by the ESNA promote avoiding unnecessary duplication of research and stimulate investigations which are complementary.

This three factors together have promoted the scientific progress in our field of interest enormously.

It is impossible to mention all speakers and to give the titles of all lectures, in fact they are listed in this report. However, an exception has to be made for a lecture all of us enjoyed very much, and this exception is then for the opening lecture by Prof. Jansson: Nitrogen utilization and losses within the agricultural ecosystem.

There was also something regrettable, the ESNA committee did again not succeed to avoid severe overlapping of the various working group sessions. Let us hope, this can be improved next year in Brno, Czechoslovakia.

X

It has been decided by the ESNA Committee that short reports or abstracts on nuclear methods which are relevant for the working groups can be included in the Newsletters of the working groups concerned. Such contributions should be very short. They are reproduced by photocopying, sloppy originals will give sloppy copies.

Other papers published are:

S.L. JANSSEN. Nitrogen utilization and losses within the agricultural ecosystem

M.J. FRISSEL. Nitrogen cycling in agro ecosystems. Some summarizing data

S. GHOSHAL. Nitrate reduction in model soil columns

M. KRÁLŮVKA, J. KUBAT, B. NOVÁK and K. DRAZDÁK. N-study of N-mineralization-immobilization in soil, particularly in the presence of added glucose

B. LINDEN. Movement and fate of autumn and spring applied nitrogen in clay soils.'

R. FILIPOVIC and S. SIMIC. Studies on conservation of added nitrogen fertilizers in soil and possibility of underground water pollution by nitrogen residues.

H. NOMMIK and J. THORIN. Use of ¹⁵N technique for in situ measurements of denitrification in lakes.

L. CALANCEA, M. BOLOGA and V. FIRU. Use of ¹⁵N studies of effects of urease inhibitors.

S. STAN, G. SUTEA, Cr. HEAR, Z. BORLAN and A. STANCIU. Study of the phosphate fertility modifications in a chernozem type soil under long term N and P fertilization, by chemical and isotopic methods.

E. HAAK. Isotope added studies in cereals on the relative uptake of Ca, P and K from plow layer and subsoil.

G. GISSEL NIELSEN. Use of ⁷⁵Se in the study of uptake and translocation of selenium in plants.

E. HAUNOLD and F. ZSOLDOS. The effect of 2,4-D and MCPA on the influx and efflux of ⁸⁶Rb (k) and ³²P in wheat roots.

A. ERIKSSON and F. KARLSTROM. A field technique for studies on plant root development and bio-activity.

- M .J.FRISSEL.Root activity patterns of some tree crops (A review of Technical Report n°170 of the Joint FAO/IAEA Division of, Atomic Energy in Food and Agriculture in Vienna).
- S.C.VAN DE GEIJN.In vivo measurements of ion transport and cation exchange capacity of the xylem of transport systems by means of semiconductors.
- S.RATKOVIC and B.BOZOVIC.A proton NMR study of H_2O - D_2O exchange in root systems.
- K .A.SMITH.Problems of quantitative assessment of denitrification
- A.DOMNICZ.Influence of Mg on accumulation and distribution of ^{42}K and ^{35}S in oat plants.
- I.C.PALTINEANU, R.PALTINEANU, I.APOSTOL and M.A.SANJRANI.Preliminary results on irrigation water and nitrogen fertilizer application efficiencies for the reduction of water and nitrogen losses and water pollution control.
- I.C.PALTINEANU , R.PALTINEANU, I.APOSTOL and M.A.SANJRANI.Neutron method use in studies of drip, sprinkler and furrow irrigation of field crops.
- ⁵⁴
M.M.EBEID.Adsorption of Mn by soils in relation to their properties
- ⁵⁴
M.M.EBEID. Mn uptake by flax seedlings and its distribution.

X

ESNA Secretariat send us also the N°9 of the Newsletter on the Application of Nuclear Methods in Biology and Agriculture (Wageningen in january 1978) initiated under the auspices of ESNA by the Association EURATOM ITAL (P.O.Box 48.Wageningen The Netherlands).

The aim of the Newsletter is providing information on radiological methods about "Labelling techniques" and "Radiation techniques" and their applications in agricultural and biological research.It is meant to draw the attention of scientists engaged in agricultural and biological investigations to the possibilities of these methods and applications for their problems.

None of the information obtained in the research notes can be used in publications without consent of the authors concerned.

The Newsletter is only distributed to members of ESNA.

N°9 content following 2 papers:

- 1.Labelling techniques: An autoradiographic method for studying the root distribution and spread of apple tree in the soil. par KATANA H. and KUHN W.
- 2.Radiation techniques: Investigation of the total chlrophyll content in plants grown under different light conditions from seeds irradiated with ionizing radiation.

XXII.LIVRES NOUVEAUX. LIST OF NEW BOOK

- B.J.BARFIELD and J.F.GERBER.ASAE Monograph on Modification of the Aerial Environment of crops.1977.American Society of Agricultural Engineers.St **Joseph** Michigan USA.
- A.J.BERTINCHAMPS ed.Effects of ionizing Radiation on DNA.1978 Springer Verlag 420 pages DM.86.
- C.BROERTJES and A.M.Van HARTEN.The application of mutation breeding methods in the improvement of vegetatively propagated crops.1978.Elsevier Scientif. Publ.Cy, 296 pages.Dfl.130.
- Compte rendu 1977.du Centre National d'Experimentation des plantes medicinales, SNPPM.Milly la Fort BP 38. 91490.France.
- G.S.CAMPHELL.An introduction to environmental biophysics 1977.Springer Verlag 159 pages, 8, 904^a.
- European Horticultural Statistics.VolN°25, 1977.Edited by AIPH Postbox 361.The Hague Netherlands.D.Fl.28.
- M.T.FERAUGE et J.P.SMAL.Dix annees de recherches our le pommier 1977.5 volumes.
I.Problames de nutrition poses par la couverture vegetate du sol en vergers de pommiers.II.Travaux preliminaires A l'emploi de la technique phytotronique en culture de pommier.ItI.Nutrition equilibree du pommier en aquiculture.IV.Observations sur certaines reactions du pommier son environnement en culture contalee. V.Quelques particularites **de** la nutrition du pommier en relation avec l'organe d'absorption.
Edition IRSIA.CNECF.Bruxelles.
- K.FRANKEL and E.GALUN.Pollination Mechanisms, Reproduction and plant breeding. Springer Verlag 1977, 281 pages D.M.60.
- M.J.FRISSEL.Cycling of mineral nutrients in Agricultural Ecosystems.1978.Elsevier Scientific Publ.Cy.352 pages Dfl.95.
- C.GIEBISCH ed.Membrane Transport in Biology.Vol.3.Transport across Multimembrane systems.1978.Springer Verlag.D.M.148.
- U.GRENANDER.Pattern Analysis.1978 Springer Verlag 605 pages D.M.32.
- R.GUDERIAN.Air Pollution, 1977, Springer Verlag 150 pages D.M.58.

- J.L.GUIGNARD.Abregé de Botanique.Ed.Masson Paris 1977.257 p. 49 F.F.
- F.HALLE and al.Tropical trees and Forests.1978.Springer Verlag 450 pages.D.M.125.
- J.J.HANAN and al.Greenhouse management.1978.Springer Verlag , 560 pages.D.M.94.
- P.H.HOFSCHNEIDER Ed.Integration and excision of DNA molecules.1978.Springer Verlag 200 pages D.M.48.
- I.V.T.Phytotron 1953-1978.Plant Breeding Research under controlled conditions in horticultural crops.Neth.J.Agric.Science Vol.26 , 1978, 132 pages.
- K.G.KARYTCHEV and al.Portes-greffes et pepinieres pour plantations intensives (en Russe) Ed.Kainar Alma Ata USSR, 1977, 102 pages.
- D.D.KOO.Elements of optimization.1977, Springer Verlag 200 pages, D.M.18, 50.
- W.KRAUSE (dir.publ.).Application of vegetation science to grassland husbandry. Dr.W. Junk Publ.Den Haag 1977, 535 p.
- K.KUBITZKI ed.Flowering Plants.Evolution and classification of Higher Categories 1977, Ed.Springer Verlag 420 pages.DM.198.
- O.L.LANCE and all.Water and plant life:problems and modern approaches.1976.Springer Verlag 49, 20
- Presentation J.M.PERES.Les processus de la production vegetale primaire.Ed.Gauthier Villars Paris 1977, 265 p.150 F.F.
- A.POGGI.Introduction à la micrometeorologie:transferts d'energie atmosphere, sol. Ed.Masson Paris 1977, 148 p.80 F.F.
- E.G.RAUSIN.Horticulture de montagne (En Russe)Ed.Kainar Alma Ata USSR.1977, 184 pages.
- R.S.DE SANTO Ed.Environmental management.vol.1 1977 D.M.144, vol.2.1978 D.M.144. Ed.Springer International.
- R.S.DE SANTO.Concepts of Applied Ecology.1978 Springer Verlag 320 pages.D.M.21, 40.
- P.R.STEWART and D.S.LETHAM Ed.The Ribonucleic acids 1977 Springer Verlag 374 pages D.M.47, 40.
- D.C.TOSTESON.Ed.Membrane Transport in Biology Vol.1.Concepts and Models .1978 Springer Verlag D.M.148.
- A.TRONCHET.La sensibilité des plantes.Ed.Masson Paris 1977, 158 pages.
- The third Eucarpia meeting on Capsicum Genetics and Breeding.Edited by Mr.E.POCHARD INRA.Domaine St Maurice.84140.Montfavet France.F.F.50.
- Technical communications of ISHS.Copits can be ordered from the secretariat of the society:Bezuidenhoutseweg 73 (P O B 20401) The Hague.Netherlands.
- N°67.Fruit Tree Virus diseases.September 1976 Heidelberg Print in may 1977, 342 pp.
- N°68.Flower formation in Ornamentals.September 1976 Pisa.Print in february 1977. 188 pages.
- N°69.Pear growing .Florence october 1976.Print in february 1977.333 pp.

- N°70. Energy problems in greenhouses. Karlst the September 1976. print in May 1977.
160 pages.
- N°71. Carnations. Antibes, May 1977. Print in October 1977 298 pages.
- N°75. Clonal Variation in Apple and Pear. Renesse, august 1977 Print in November 1977.
185 pp.
- N°77. Fifth Symposium on Horticultural Economics. Budapest September 1977. Print in
January 1978. 423 pp.
- N°78. Tissue culture for horticultural purposes. Ghent, September 1977. Print in december
1977 459 pp.
- N°79. Propagation and raising of nursery stock. Dublin september 1977. Print in february
1978 168 pp.
- N°82. Production of protected crops in peat and other media, Dublin september 1977.
Print in february 1978. 250 pp.

X

X

X

XXIII ARTICLES SISNALES, ARTICLES IN PRINT

- B.J. BAILEY. Research on thermal screens at N.I.A.E. Plasticulture 1978, n°38, p.27-36.
- M. BAILLE et al. The Heating of greenhouses by water circulation in plastics film
tubes laid out on the soil: microclimatic study and agronomic results.
Plasticulture 1977 n°36 p.13-29.
- D.H. BALSAYER. Nutrient Film Technique trials at Urulikanchan. India Plasticulture 1977
n 35 p.33-36.
- BEHBOUDIAN M.H. Responses of egg plant to drought. I. Plant water balance. Scientia Horti-
culturae 7, 1977, 303-310.
- BEHBOUDIAN M.H. Responses of egg plant to drought. II. Gas exchange parameters. Scientia
Horticulturae 7, 1977, 311-317.
- BEHBOUDIAN M.H. and H.M.C.v. HOLSTEIJN. Water relation of lettuce. I. Internal physical
aspects for two cultivars. Scientia Horticulturae 7, 1977, 9-17.
- E. BEITZ. Plastics materials in the nursery. Plasticulture 1977, n°36, p.44-49.
- BLONDON F. Nouvelle conception sur faction de facteurs externes responsables de is
floraison: applications pratiques. C.R. Acad. Agric. France 1977, 63, 331-
349.
- M. BOULAY. L'horticulture en zones arides. PHM 1978 n°185 p.15-21. PHM 1978 n°187, p.17-24.
- BURSTROM H.G. Tissue structure and hormone responses . Plant Science Letters 10, 1977,
341-345.
- M. CHAUMOND. L'emploi des nanifiants en horticulture ornementale. PHM 1978, n°184, p.33-35.

- COOPER A.J. and R.R.CHARLESWORTH. Nutritional control of a nutrient film tomato crop. *Scientia Horticulturae* 7, 1977, n°3, p.189-198.
- DESBOROUGH P.J. Evaluation of cool-season, annual legume species on alkaline, cracking clay soils at Narrabri, New South Wales. I. Initial survey. *Australian Plant Introduction review* 1976, vol. II, n°2-3, p 2-16.
- DOORENBOS J. Spontaneous mutation as a source of clonal variation on deciduous fruits. *Acta Horticulturae* n°75, 1977, 13-18.
- J.S.DOUGRAMEJI. Experimental Station Euphrates; drainage studies at Beni Tagleb Basin, Syria. Soil Science Division. Damascus 1977. ACSAD/SS/P5/77.
- I.H.EL BAGOURI. The use of saline water for irrigation and its effects on soil and plants under the conditions of arid zones. Damascus 1977, Soil Science Division. ACSAD/SS/P4.
- FISCHER P. and J.HANSEN. Rooting of Chrysanthemum cuttings. Influence of irradiance during stock plant growth and of decapitation and disbudding of cuttings. *Scientia Horticulturae* 7, 1977, n°3, p 213-224
- FOLSTER E. and H.KRUG. Influence of the environment on growth and development of chives (*Allium schoenoprasum* L.) . II. Breaking of the rest period and forcing. *Scientia Horticulturae* 7, 1977, n°3, p.213-224.
- FURUYA M. Photomorphogenesis in plants. In *Recent Progress of Natural Sciences in Japan* 1977. vol.2, 45-69.
- S.GASPAR DAUTREBANDE. Modelisation mathematique en hydrologie forestiere. *Annales de Gembloux* 1977, 83, n°1, p.19-25.
- General Report Meeting of the Arab Countries in preparation for the UN Conference on desertification. 25-29 juin 1977. Bludane. Soil Science Division ACSAD/SS/R13.20 pages.
- M.GERARD. Intéret de la substitution partielle du chauffage du sol à celui de l'air en culture horticole sous abris. *PHM* 1978, n°183 p.13-19.
- G.GILLY. La fertilisation du chrysanthème cultivé pour la fleur coupée. *PHM* 1978, n°186, p.25-30.
- M.GUARIENTO and V.RAVELLI. The protected cultivation of sweet peppers in the Po valley. *Plasticulture* 1978 n°38 p.3-18.
- G.GUYOT. Calculation of the wind stresses on windbreaks. *Plasticulture* 1977 n°36, p.31-43.
- HARSSEMA H. Root temperature and growth of young tomato plants. *Meded. Landbouoges.* Wageningen 77, 19, 1977-1-85.
- HAYNES R.J. and K.M.GOH. Review on physiological pathways of foliar absorption. *Scientia Horticulturae* 7, 1977, n°4 p.291-302.
- V.HOLSTEIJN H.M.C., M.H.BEHBOUDIAN and G.C.M.L.BONGERS. Water relations of lettuce. II. Effects of drought on gas exchange properties of two cultivars. *Scientia Horticulturae* 7, 1977, 19-26.
- JONKERS H. An experiment to induce early pear cropping by the use of growth regulators and shoot tipping. *Acta Horticulturae* 69, 1977, 169-174,
- J.KREKULE and F.SEIDLOVA. *Brassica cappestris* as a model for studying the effects of exogenous growth substances on flowering in long-day plants. *Biologia Plantarum* 1977, 19(0), 462-468.

- H.KOHSSTALL.The propagation of ligneous plants in plastics tunnels.Plasticulture 1978 n°37, p.45-52.
- LANGTON F.A.The responses of early flowering chrysanthemums to daylength.Scientia Horticulturae, 7, 1977, n°3 p.277-289.
- M.H.LOAE.C.Nouveaux acquis de la recherche pour la connaissance du Begonia .Rieger PHM 1978, n°185, p.43-46.
- MARKIN V.V. and V.P.CHITOVA.Appareillage pour irradiation monochromatique en biologie. Problemes de photobiologie pratique.1977 Poustchino URSS p.92-95 (en Russe).
- A.E.MATAR and al.Diagnosis and control of lime-induced chlorosis on olive trees grown under dry farming conditions by iron chelates.Damascus 1977, Soil Science Division AcSAD SS/P6/77.
- P.MATHY.Quelques problemes relatifs aux effets et aux consequences de la pollution atmospherique sur la foret.Annales de Gembloux 1977, 83, n°1, p.61-67.
- MEETEREN U.van.Water relations and Keeping quality of Cut Gerbera flowers.I.The cause of stem break.Scientia Horticulturae 8, 1978, 65-74.
- H.MOULINIER et M.MONTARONE.La nutrition du Gerbera .PHM 1978, n°188 p.13-18.
- NOTHMANN J.Effects of soil temperature on head development of Cos lettuce.Scientia Horticulturae 7, 1977, n°2, p.97-106.
- E.NUERNBERGK.Versuche mit einem Kleinen Plexiglas.Gewadrshaus.Die Orchidee 1978 29, 127-136.
- PALZKILL D.A., T.W.TIBBITTS and P.H.WILLIAMS.Enhancement of calcium transport to inner leaves of cabbage for prevention of Tipburn.J.Amer.Soc.Hort.Sci.101 (6) 1976, 645-648.
- REES A.R.The cold requirement of tulip cultivars.Scientia Horticulturae 7, 1977, n°4 p.383-389.
- REID J.B. and I.C.MURFET.Flowering in Pisum:the effect of Genotypes Plant Age, photo-period and number of inductive cycles.Journ.of Exp.Bot.1977, vol.28, n°105, 811-819.
- REID J.B. and I.C.MURFET.Flowering in Pisum:the effect of light quality on the genotype if e Sn H.J.Exp.Bot.1977 vol.28 n 107, 1357-1364.
- REID J.B., P.J.DALTON and I.C.MURFET.Flowering in Pisum:Does Gibberellic Acid directly influence the flowering process? Aust.J.Plant Physiol.1977, 4, 479-483.
- F.ROBLEDO de PEDRO.Plastics materials in Spanish agriculture:statistics, analysis and Prospects.Plasticulture 1977, n°35, p.3-19.
- ROORDA van EYSINGA J.P.N.L. and H.E. van CAEM.Nutrition of glasshouses strawberries with nitrogen, phosphorus and potassium, Scientia Horticulturae 7, 1977, n°4, p.359-368.
- A.SANS DRAP.Le paillage plastique du fraisier.PHM 1978, n°185, p.25-29.
- SVENTIZKY I.I.Appreciation qualitative de l'efficacite photosynthetique des radiations optiques.Problemes de photobiologie pratique 1977.PoustchinoURSS, p.73-75 (en Russe).

- Y.TERMONIA.A thermodynamic approach to the problems of ecology.Annales de Gembloux
1977, 83, n°2 p.133-140.
- TESI R.L'Illuminazione artificiale nella orticoltura di serra.Colture Protette, 6,
1977 n°3, p.47-57.
- TESI R.Esigenze climatiche e condizionamento della serra nella coltura della Rosa,
Giornate di Floricoltura Sulla Rosa.S.Remo Italia, Maggio 1977, 1-16.
- TESI R.La canalizzazione dell'aria calda nella economia degli impianti di riscaldamento.
Colture Protette, 5, 1977, n°12 p.43-45.
- M.VERDURE.Cultures sous serre dans la tourbe ou dans d'autres substrats.PHM 1978,
n°187 p.55-60.
- H.VIDALIE.Influence de la duree de conservation au froid sur le forage de l'Hortensia
(Hydrangea macrophylla).PHM 1978, n°187, p.11-15.
- WADA M. and M.FURUYA.Effects of Narrow beam Irradiations with Blue and Far-red Light
on the Timing of Cell Division in Adiantum gametophytes.Planta 1978, 138,
85-90.
- J.N.WALKER and G.A.DUNCAN.Reducing energy losses from greenhouse structures.Plasti-
culture 1978 n°37 p.3-14.
- WELLENSIEK S.J.Principles of flower formation.Acta Horticulturae n°68, 1977, 17-27.
- XLa Tomate :les cultures sur substrat, la qualita.PHM 1978 n°188
p. 33-38.
- X Quelques avantages de la production de plants forestiers en conte-
neurs.PHM 1978, n°184, p.51-55.

XXIV. REUNIONS ET EXPOSITIONS ANNOUNCES COMING EVENTS, MEETINGS

1978. August 14-18 Hamar (Norway)
Joint Symposium on Landscaping in peatlands (ISHS/IPS)
Inf.Mr.A.GARKIN-Bulewardi 31.Helsinki 18 Finland
1978. August 28-September 1.Japan
International Symposium on Potential Productivity in Protected cultivation
organised by Japanese Society of Horticulture.
Inquiries: Dr.T.TAKAKURA Dept.Agric.Eng.Univ.of Tokyo Yayoi Cho, Bunkyo-Ku
Tokyo, Japan 113.
1978. September 3-8 Munich (G.F.R)
First Int.Congress of Mycology
Inf.H.J.Preusser Schnittpahnstrasse 10
D 6100 Darmstadt G.F.R.

1978. September 3-9. The Hague (The Netherlands)
Fourth Int. Congress on Virology
Inf.: Congress Centre P.O. Box 9000 The Hague (The Netherlands)
1978. September 3-9 (Poland or Israel)
8th International Biometeorological Congress
Inf. Prof. C.L. BARGER
I.S.B. Permanent Committee on the Effects of Climate and Weather on Plants.
110 Federal Building Columbia Miss. 65201. USA
1978. September 4-8 Gembloux Belgique
International Study Week. Statistics and Computer Science in Agriculture
Inf. Prof. P. DAGNELIE, Faculte des Sciences Agronomiques de l'Etat
58000 Gembloux Belgique 1
1978. Septembre 4-8 Gembloux Belgique
Semaine d'etude internationale: Statistique et informatique en Agronomie
Renseignements: Prof. P. DAGNELIE, Faculte des Sciences Agronomiques
58000-Gembloux Belgique
1978. September 4-8 Wye College (UK)
Symposium on Labour and Labour management
Inquiries: J.A.H. NICHOLSON School of Rural Economics and Related Studies
Wye College Nr Ashford Kent TN 25 5 AH UK
1978. September 4-9 BRNO (Czechoslovakia)
IXth Annual Meeting of European Society of nuclear Methods in Agriculture (ESNA)
Inf. ESNA Secretariat. P O Box 48. 6700 AA, Wageningen (The Netherlands)
1978. Septembre 8-10 Orleans (France)
Hortimat. Exposition, Demonstration equipment horticole
Inf. Parc des Expositions Orléans 45000 France.
1978. Septembre 8-11 St Quentin (France)
Festival du Dahlia
Inf. Soc. Française du Dahlia, rue de Baudreuil 02100 -St Quentin (France)
1978. September 8-13 Ibadan (Nigeria)
Conference on stored Product Entomology
Inf. Dir. Inst. of Agr. Res and Training P M B 5029
Moor Plantation Ibadan (Nigeria)
1978. September 10-16 Jerusalem (Israel)
Second international Congress of Ecology
Inf. INTECOL c/o Conventions Kopel 122, Hagarkon str. P O Box 3054, Tel Aviv, Israel.
1978. September 12-15 Reading (UK)
The role of plant foods on preventive medicine
Inf. Prof. W. SCHUPHAN, Heidestr. 9 D-6222 Geisenheim Rheingau (G.F.R.)
1978. Septembre 12-15 Berlin (G.F.R.)
International Congress on Date Processing
Inf. Ausstellungen-Messe-Kongress GmbH Messedamm 22 D 1000 Berlin 19
1978. September 17-22 Kyoto (Japan)
Vth int. Congress of Food Sci. and Technology
Inf. Prof. H. MATSUDA, Kyoto Univ. Fac. Agric. Oiwake Cho-Sakyo-Ku Kyoto (Japan)

1978. Septembre 21 Paris (France) Conference on Weed Problems Inf.Dr.G.MATHYS, EPPO I rue Le Natre, 75016-Paris (France).
1978. 3-5 Octobre Grignon (France)
Connaissance de l'a_griculture:Le travail du sol
Renseignements: Adeprima, 16 rue Claude Bernard, 75331 Paris Cedex 05.
1978. 3 au 5 Octobre Versailles (France)
Stage de formation continue a l'ENSH:Energie lumineuse et production horticole
problAme de l'eclairment d'appoint
Renseignements: ENSH, Formation continue, 4 rue Hardy, 78000 Versailles (France)
1978. October 4-6 Littlehampton (UK)
Eucarpia meeting on Chrysanthemum Breeding
Inf.Dr.F.A.LANCTON, Glasshouse Crops Res.Inst.Worthing Road Littlehampton
Sussex BN 16-3 PU UK
1978. October 5-29 Valencia (Spain)
IBERFLORA.International Horticulture Exhibition
Inf.Iberflora Apartado de Correos 13 Valencia (Spain)
1978. 10-12 Octobre Grignon (France)
Cycle de Formation continue;le marketing agro-alimentaire et la prise de deci-
sion
Renseignements;Adeprina, 16 rue Claude Bernard, 75231, Paris Cedex 05.
1978. 17 au 19 Octobre Versailles (France)
Stage de formation continue A l'ENSH: Methodologie pour l'etude des paysages en
vue de leur aménagement
Renseignements : ENSH Formation continue, 4 rue Hardy, 78000 Versailles (France)
1978. October 17-21 Utrecht (The Netherlands)
Trade fair Garden and Park
Inf.Joke Stalpers Royal Neth. Ind.Fair, Jaarbeuspleinljlrecht The Netherlands
1978. October 23-28 Taiwan (Rep.of China)
First international symposium on tropical tomato .Info.Dr.R.L.VILLAREAL.
AVRDC.PO Bok 42.Shanhua Tainan 741.Taiwan (Rep.of China).
1978. 7-9 Novembre Paris (France)
Cycle de formation continue, Techniques recentes au service de l'analyse chimique
Renseignements:Adeprina 16 rue Claude Bernard, 75231 Paris Cedex 05
1978. 9-12 Novembre Chateauroux France
Salon CongrAs International du Chrysantheme
Inf.O N I H B P 309 94152 Rungis (France)
1978. 13-15 et 20-22 Novembre Paris (France)
Cycle de Formation continue:Germination des semences
Renseignements:Adeprina 16 rue Claude Bernard, 75231-Paris Cedex 05
1978. 14 au 17 Novembre Versailles (France)
Stage de Formation continue A l'ENSH. Maladies et ennemis des especes ligneuses
A vocation paysage
Renseignements:ENSH Formation continue 4 rue Hardy 78000•Veisailles France
1978. 28 au 29 Novembre Versailles (France)
Stage de Formation continue a l'ENSH:Rotations et cultures de remplacement en
productions horticoles
Renseignements:ENSH Formation continue 4 rue Hardy 78000 Versailles (France)

1978. 28-29 Novembre Grignon (France)
Connaissance de l'Agriculture:l'ensilage
Renseignements: Adeprina 16 rue Claude Bernard 75231 Paris Cedex 05
1978. 5-9 Decembre Paris(France)
Semaine internationale de t'environnement
Renseignements: GERP 12 rue Chabanais 75002 Paris (France)
1978. 5-12 Decembre Paris France
2e Exposition professionnelle d'amenagement et entretien des Espaces verts et equipements sportifs
Inf. GERP 12 rue Chabanais 75002 Paris (France)
1978. December 11-15 Colombo (Shri Lanka)
Intern.Symposium on the Use of isotopes and radiation in research on soil Plant Relationship
Inf.FAO/IAEA Vienna Austria
1978. 12-14 Decembre Grignon (France)
Cycle de Formation continue:Le choix des ecpipements de production en agriculture
Renseignements: Adeprina, 16 rue Claude Bernard 75231 Paris Cedex 05
1979. Wageningen (The Netherlands)
ISHS Symposium:Computers for greenhouse environment control
Inquiries:G.H.GERMING IMAG, Postbox 43 Wageningen The Netherlands
1979. N.W.Europe
Vlith Symposium on Horticultural Economics
Inf.lf W.G.de HAAN Agric .Economic Inst.Conradkade 175 The Hague Netherlands
1979. Brazilia (Brasil)
Second South American Symposium on Vegetable crop research
Inf.Dr.L.A.MONTOYA IICA Caixa Postal 16-074
ZC 01, 20000 Rio de Janeiro Brazil
1979. Nigeria
VI;Africa Horticultural Symposium on indigenous vegetables
Inf.H.D.THINDALL , Nat.Coll.of Agric.Engin.Silsoe Bedford MK 45 4DT England
1979. Budapest (Hungary)
II Symposium on small fruit virus diseases
Inf.Dr.R.STACE SMITH Res.St.Agric.Canada 6660 N.W. Marine Drive Vancouver
B.C.V6T 1X2 Canada
1979. January 26-February 4 Berlin (G.F.R)
International Green Week
Inf.Ausstellungs Messe Kongress GmbH Messedamm 22 , D 1000 Berlin 19
1979. February Christchurch (New Zealand)
Int.Symposium on reproduction in flowering plants
Inf.E.J.GODLEY Botany Div.Dept of Scientific and Ind.Research.Private Bag
Christchurch (New Zealand)
1979. Februray 14 Peterborough (UK)
Conference on Vining Peas
Inf.A.J.GANE PGRO Res.Sta.Great North. Road Thornhaugh Petterborough PE8 6HJ UK
1979. Spring Avignon (France)
Multidisciplinary meeting on "Growth optimalisation through microclimate control
Inquiries: K.W.WINSPEAR NIAE Wrest Park Silsoe Bedford MK 45 4HS (UK)

1979. March Kerala State (India)
ISMS Symposium on Cashew nuts
Inquiries: J.G.OHLER Tropical Institute: Mauritskade
63 Amsterdam 0 The Netherlands
1979. March 12-14 Madison (USA)
Controlled Environments Working Conference
Inf.Prof.T.W.TIBBITTS Horticulture Dept.Univ.of Wisconsin Madison 14.s.
53706 USA
1979. March 21 Peterborough (UK)
Conference on Mechanisation in the Production of Vegetables for processing
Inf.A.J.GANE PGRO Res.St.=Great North Road Thornhaugh Peterborough PE8 6HJ (UK)
1979. April 1-7 Canterbury (UK)
ISHS Conference on mineral nutrition and fruit 13..la 4ty of temperatre zone fruit trees
Inf.Dr.D.ATKINSON East Mailing Research Station Maidstone Kent ME 19 6 BJ UK
- 1979, 5-10 Avril Bordeaux (France)
Exposition florale de Bordeaux
Renseignements:M.D.GONZALEZ Martignes sur Jalles 33610-Gazinet Cedex 05
1979. 11-21 Mai et 23 Mai-3 Juin Paris (France)
Floralies Internationales de Paris 1979
Renseignements: CNIH BP 309 ⁹⁴¹⁵² Rungis Cedex.
1979. May 14-17 Skiersiewice (Poland)
Symposium on Growth regulators in floriculture ISHS
Inf.Prof.Dr.R.M.RUDNICKI Ul Pomologiczna 18 96100 Skierniewice Poland
1979. June 11-15 Alnarp (Sweden)
First Symposium on quality of vegetables
Inf.Dr.Torsten NILSSON Dept.of Vegetable Crops Agric.Col.Sweden
S.230 53 Alnarp Sweden
1979. June 25-July 1 Budapest (Hungary)
Second ISHS symposium on Spices and medicinal plants
Inf.Dr.P.TETENYI Gyogynoverly Kutato Intezet PF 11, H 2011 Budakalasz Hungary
1979. July 8-13 East Lansing USA
9th International Congress on Rural Engineering organized by Michigan State University and American Society of Agricultural Engineers
Inquiries: Prof.C.M.HANSEN CIRG Congress Coordinators 113 B Agricultural Engineering Bldg Michigan St.Univ.East Lansing Mich.48824 USA
1979. August Aarslev (Denmark)
Symposium on Production planning in glasshouse floriculture
Inf.Dr.V.A.HALLIG Glasshouse Crops Research Station Kirstinebjergvei 10,
DK 5792 Aarslev (Denmark)
1979. August EVORA (Portugal)
ISHS symposium on production on tomatoes for processing
Inf.Prof.C.A.M.PORTAS Inst.Univ.d'Evora Apartado 94 Evora Portugal
1979. August Northern Europe
ISHS symposium on International transport systems fot maximzing the labour efficiency of greenhouse
Inf.Dr.H.G.GERNING I MAG P 0 BOX 43 Wageningen (Netherlands)

1979. August 20-September 5 Khabarovsk (USSR)
XIV Congress of Pacific sciences
Inf.Organizing Comm.49 Vavilov Str.V 333 Moscow 117333 (USSR)
1979. August or September Israel
8th international Biometeorological Congress
Dr.N.St G HYSLOP Animal Diseases Res.Inst. PO Box 11300
Postal Station H Ottawa Ont K2H 8P9 Canada
1979. September 11-13 Littlehampton (UK)
Research on recirculating water culture symposium NFT
Inf.Dr.D.BLANC Centre de Recherches Agron.d'Antibes BP 78 06602 Antibes (France)
1979. November 3-6(Philippines) Los Banos
ISHS Symposium on problems in fruit and vegetable crgp research
Inf.Dr.E.B.PANTASTICO Coll.of Agriculture Univ.of Philippines Laguna Philippines
- 1979 or 1980 Wageningen (Netherlands)
ISHS Symposium on vegetable storage
Inf.Ir.W.S.DUVEKOT Sprenger Inst.Haagsteeg 6 Wageningen (The Netherlands)
- 1979 or 1980 Israel(?)
Symposium on (rootstocks) fruit quality and yield improvement in Mediterranean Citrus
Inf.Dr.S.P.MONSELISE Dept.of Horticulture POB 12 Rehovot (Israel)
1980. 6 months Exposition nationale horticole, Bille (Suisse)
1980. Probably Lund (Sweden)
ISHS Symposium: More profitable use of Energy in Protected cultivation
Inquiries: G.H.GERMING DRAG Postbox 43 Wageningen The Netherlands
1980. Merano (Italy)
ISHS Symposium on Hicgh density planting
Inf. J.E.JACKSON East Malling Res Sta.East Melling Kent ME 19-6 BJ UK
1980. Italy
ISHS Symposium on Vegetable seed production
Inf.Dr.R.A.T.GEORG School of Biological Sc.Univ.of Bath Claverton Down Bath
Somerset (UK)
1980. Evian France
VIII Congress of the Inst.Ass.of Photobiolog
Inf.Prof.C.HELENE Centre Biophysique Moleculaire 45045 Orleans Cedex France
1980. Brunswick (RFG)
Fifth ISHS Symposium on virus diseases of ornamental plants
Inf.Dr.R.KOENING Inst.fur Virusserologie Messeweg 11/12 Baunschweig BRD
1980. May 12-17 Aarslev (Denmark)
Third ISHS Symposium on Flower Bulbs
Inf.Dr.E.RASMUSSEN State exp.Station Aarslev DK 5792 Denmark
1980. Avril Gand Belgique
Floralies gantoises
1980. August Davis Calif.(USA)
find Int.Symposium on Post harvest physiology of cut flowers
Inf.Prof.A.M.KOFRANEK Dept of Environmental Horticulture Univ.of California
Davis CA 95616 (USA)

1980. August 19-28 (North America)
Symposium on Rubus
Inf.H.A.DANBENY Vancouver Res.Sta.6660 NW Marine Drive Vancouver BC V6T 1X2
Canada
- 1980 or 1981 (UK)
ISHS Symposium on timing field production of vegetables
Inf.Dr.D.GRAY Nat.Vegetable Res.Sta.Wellesbourne Warwick CV 35 9 EF UK
1981. 21-28 August Sydney Australia
XIII International Botanical Congress
Inf.University of Sydney NS W 2006 Australia
1981. Avril Genes (Italie)
Euroflora
1982. 6 months Floriades des Pays-Bas
1982. Hambourg (FRG)
21st International Horticultural Congress
Inquiries: Prof.D.FRITZ Institut für Gemüsebau 8050 Weißenstephan Freising/00B
Germany Fed.Rep.
- 1982-1983 August Aarslev (Denmark)
Production planning of Glasshouses Floriculture (ISHS)
Inquiries: V.A.HALLIG Research Institute for Glasshouse Crops
Kirstinebjergvej 10, DK 5792 Aarslev Denmark
1983. 6 months IGA a Hambourg (FRG)
1984. 6 months WIG, Vienne (Autriche)
1985. Avril Floralies &antoises (Belgique)

x

Nous remercions à l'avance, tous ceux qui nous enverront des informations ou articles que nous reproduirons, si possible, dans les prochains numéros.

We thank, in advance, all those who will be sending us reports or news to print in coming issues.

R.JACQUES and N.de BILDERLING.