LABORATOIRE DU PHYTOTRON - 91 - Gif s/ Yvette

PHYTOTRONIQUE

SCIENCE, TECHNIQUE ET RECHERCHES SUR
LES RAPPORTS ENTRE L'ENVIRONNEMENT
ET LA BIOLOGIE DES VEGETAUX

COMPTE RENDU DE LA TABLE RONDE
TENUE AVEC L'AIDE DE LTUNESCO

LONDRES, 30-31 JUILLET 1964

EDITIONS DU CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

15, Quai Anatole France . Paris (7e)

1969

PHYTOTRONIQUE

SCIENCE, TECHNIQUE ET RECHERCHES SUR LES RAPPORTS ENTRE L'ENVIRONNEMENT ET LA BIOLOGIE DES VEGETAUX

⁂

Compte Rendu de la Table Ronde de Phytotronique, tenue a Londres les 30-31 Juillet 1964.

Edits par

P. CHOUARD - Professeur a la Facultti des Sciences de Paris
Directeur du Phyrotron du C.N.R.S. a Gif-sur-Yvette -91-

N. de BILDERLING - Ingenieur de Recherches au C.N.R.S.
Le Phytotron - Gif-sur-Yvette -91-

Table Ronde tenue avec ('aide de ('UNESCO ; Compte Rendu edits par le Phytotron
a Gif-sur-Yvette , avec ('aide du Centre National de la Recherche
Scientifique (C.N.R.S.), 15 Qua; Anatole France, Paris Vileme.

AVANT PROPOS ET SOMMAIRE

-A-

D'abord des excuses a nos lecteurs comme d nos auteurs :

Apres la Table Ronde de fin juillet 1964 a Londres, et comme it arrive souvent en pareille circonstance, bien des exposes oraux interessonts ont etc fort longs a reunir sous une forme ecrite. Avant *que* cette tache soil achevee, mon collaborateur et oral N. *de* BILDERLING, qui avail assume le secretariat de cette Table Ronde, etait appele comme Attache Scientifique, puis C.onseiller Scientifique, a l'Ambassade de France a Moscou et s'il ne pouvait pas achever ('edition commencee, les circonstances m'imposaient trop de charges pour pouvoir le faire seul. Fintlement, apres mission accomplie, N. de BILDERLING a repris au Phytotron le poste qu'il occupait et a pu se consacrer 6 Ia miss au point finale des rapports, enfin tous revs, et du résumé des discussions, et je l'en remercie.

Malgre le temps ecoule, l'actualite de Ia plupart des documents demeure, l'interit de tous persiste et nous esperons que le document, edits par le Phytotron de Gif-sur-Yvette (France), avec l'aide du C.N.RS., pourra arnorcer, a ('occasion du Xleme Congres International de Botanique a Seale (fin coat 1969) la reprise de la cooperation interessante entre "Phytotronistes" de tous les pays.

P. CHOUARD

0
O O

-B-

En 1962, s'est reuni a Canberra le premier "Symposium sur le contrale de l'environnement", don' L.T, EVANS a presents un remarquable compte rendu dans " Environmental Control of Plant Growth" (London, Ac. Press. 1963). A *ce* moment, le mot "Phytotronique" *n'a* etc qu'evoque, mais la notion qu'il recouvre wait latente dons is penstse de tous. II a eta propose ensuite par A. LANG et P. CHOUARD pour designer 6 la fois tous les problemes techniques qui peuvent se poser dans ('exploitation rationnelle des Phytotrons dune part, et d'autre part aussi de l'ensemble de ce qUe Ion peut faire avec un phytotron ou avec quelque chose qui participe 6 Ia definition d'un phytotron. Ainsi comprise, la notion de Phytotronique s'etend de Ia technique 6 la science et aux recherches sur les rapports entre l'environnement et la biologic des vegetaux.

C'est dans le but de degrossir ce vaste sujet, d'essayer d'en preciser quelques points de depart, et d'envisager une cooperation entre "phytotronistes" (c'est-a-dire cette utilisation des phytotrons), qu'en fin juillet 1964, entre le Congres de Photobiologie d'Oxford et le Congres de Botanique d'Edimbourg, P. CHOUARD, sous les auspices et avec l'aide de l'U.N.E.S.C. O., a pu reunir, a Connaught Hall, a Londres, une "Table Ronde de Phytotronique". Cette reunion, dont la duree *a etc* obligatoirement limitee 6 deux fours, n'avait nullement la pretension de resoudre sous les problemes, mais d'en poser le plus grand nombre de fawn 6 prepare- d'aurres reunions Nationales ou In ternotionales sur des sujets plus specialises ou plus approfondis. II serail par consequent illusoire, voire inutile, de chercher dans le corepte rendu de cette reunion des resultats certains, ni des reponses definitives aux differenrs problemes qui peuvenr se poser. II faut simplement y voir une sorte de premieres approches pour un grand nombre de sujets de Phytorronique que d'autres reunions ou echanges de vues permettront de resoudre.

Nous tenons 6 remercier particulierement ['UNESCO qui o permis, grace 6 des subsides mis 6 l'epoque 6 noire disposition, de reunir un bon nombre de personnalites des plus qualifiees et dont nous reproduisons dans ce fascicule les conferences presentees, Gins' que des idees ou informations objets de discussions avant eu lieu avant ov apres la reunion et qui peuvent etre utiles aux personnes s'interessant 6 la Phytotronique ou 6 l'environnement en general. A ce dernier stade, nos remerciements s'etendent au Centre National de la Recherche Scientifique de France (C. N.R.S.) qui vient d'aider le Phytotron de Gif-sur-Yvette 6 publier cette masse de documents.

Dons le present fascicule (Phytotronique I) on trouvera donc :

A- LES TEXTES DES CONFERENCES revus et corriges par les outeurs dans l'ordreou ces conferences ont eta prononcees au tours des deux journees de reunion, suivis de commentaires et discussions s'y rapportant directement, savoir :

I- Introduction : P. CHOUARD

President de seance : Dr FRANKEL

2- Is there a basic common denominator in all Phytotron ?
D. KOLLER

3- Scientific aims of the Phytotron of Reading.
A.P. HUGHES

4- Phytotron of the Laboratory of Horticulture of the State Agricultural College, Wageningen.
J. DOORENBOS

5- New Climatic Meosuring chambers for Plant Physiological Research.
G. REEP : Introduction
F. WOLF: Technical description.

6- A critical comparison of various types of Phytotrons.
J.P. NITSCH

President de seance : Dr KRAMER

7- Phytotron in Rauisch-Holzhausen,
Technical details and experiences. R. BRETSCHNEIDER-HERRMANN

8- Design of Climatic programs in Phytotron.
R. BRETSCHNEIDER-HERRMANN

9- The influence of Climatic Gradients on P lant-growth in air-conditionning greenhouses.
W. BOTTLAENDER

President de seance : Dr EVANS

10- A propos de l'Helio-Phytotron de Gorsem C. SIRONVAL

11- Measurement of spectral energy distribution of artificial illumination in Phytotron and growth cabinet.
Y. NISHIZAKI and Y. ODA

12- The Phytotron design.
L.T. E. EVANS

President de seance Prof. LEOPOLD

13- Some comparisons between radiation in growth rooms and radiation under natural conditions.
P. GAASTRA

President de seance Prof. LANG

14- Influence of CO2, on growth and yield of oats depending on temperature and light intensity E. Von BOGUSLAWSKI

15- Genetic variation in developmental responses to light and temperature.
J.P. COOPER

16- Problems of Fundamental and applied Plant Physiology which require controlled environment.
K.K. NANDA

President de séance : Prof. CHOUARD

17- Suggestions pour une cooperation avec l'appui de ('UNESCO.
M. FRANZLE and M. WALT ER

B- LES TEXTES DE QUELQUES SUGGESTIONS POUR DISCUSSIONS et reflexions resues avant la reunion :

I- Chambers versus rooms
H.J. KETELLAPPER

2- Microclimatology
H.J. KETELLAPPER

3- Soil temperature
H.J. KETELLAPPER

4- Effect of age and stage of development on the rate of photosynthesis
P.M. CARTWRIGHT

5- Light source H.J. KETELLAPPER

6- Light intensity and quality effects on plant
F.P. ZSCHEILE

7- Phytotronics of woody species = dendroton
S.D. RICHARDSON

8- Regional large Phytotron combined with local small facilities
H.J. KETELLAPPER

C- LES COMPTES RENDUS DES DISCUSSIONS, classes par grands sujets suivonts :

I- Comment dolt 'etre un Phytotron.

II- Temperature de ('ambiance et des plontes.

III- Lumiere.

!V- Humidite de lair et du substrat.

V- Gaz carbonique de

VI- Besoins et utilisations des Phytotrons.

VII- Cooperation Internationale - Aide de l'UNESCO.

D- RESUME ET CONCLUSIONS DE LA REUNION PHYTOTRONIQUE t,Loncites Juille' 1554).-

0

TABLE DES MATIERES

C- COMPTE RENDUS DES DISCUSSIONS .-

POSTFACE

Les circonstances ayant impose a la parution de "Phytotronique I" pres de cinq annees de delai de reflexion, cares la reunion de Londres en 1964 et le lOeme Congres International de Botanique qui avait suivi aussitOt a Edimbourg, -et puisque ['avant-propos de ce volume a ete dcrit avant le lleme Congres International de Botanique de Seattle (AoCit-Septembre 1969),- it convenait de prolonger cet avant-propos par une courte "postface" &rite apres ce Congres.

* * *

En 1964, cares une longue preparation, environ 230 phytotronistes avaient participe a la Table Ronde de Londres qui fait ('objet de ce volume, 120 par correspondonce, 110 par leur presence active. Cinq ens plus tard, consulter moins de 2 mois avant l'ouverture du Congres de Seattle en 1969, 180 parmi les mimes phytotronistes avaient deja reponciu avant le Congres qu'ils s'interessaient a la poursuite des projets anterieurs. Une cinquantaine, qui ont pu venir a Seattle, ont repris contact (notamment les 28 aoi)t et ler septembre 1969) et ont discute la suite a donner d ces projets,sans engagement certes, mais dans *un* souci d'information commune et plus &endue.

Cinq propositions expriment, en résumé, ce qui ressort de tels entretiens a Seattle

1.- Avant tout, it est souhaite unanimement le developpernent dune information commune sur les techniques et les realisations des equipements phytotroniques et sur la bibliographic des publications scientifiques des phytotronistes, en vue de progresser dans la methode de conception et d'emploi des phytotrons et des equipements similaires pour les recherches scientifiques fondamentales e oppliquees. Un "bulletin de liaison" est unanimement desire, dans le sens ou des "Phytotronic News Letters"avalent ete proposees par le representant de ('UNESCO en 1964: voir ci-dessus p. 68 le texte de M.M. FRANZLE et WALTER.

N.B. Par suite d'empechements techniques, aucun representant de ('UNESCO n'a pu assister aux reunions de Phytotronique a Seattle.

2.- Sur la proposition du Professeur F.W. WENT, it a ete convenu que l'equipe du Phytotron du C.N.R.S, a Gif-sur-Yvette (1) assurerait la responscbilite de passer aux actes, de mettre en place un systeme simple et provisoire d'intercommunications et, ce faisant, de "trouver le mouvement en merchant".

3.- Chacun est d'accord pour collaborer, peu ou prou et scion ses moyens, a la fourniture des informations techniques et scientifiques definies ci-dessus (paragraphe 1) et demandees par taus.

4.- 11 est reconnu souhaitable de se rencontrer, apt& une preparation suffisante, par exemple a ('occasion des congres internationaux de Botanique (le prochain XI!erne Congres est prevu a Leningrad en 1975) et, s'il y a lieu, en des occasions similaires, relies que les prochains internationaux d'Horticulture.

5.- Observant que le Programme 8iologie International (P.B.1. =1.B.P.), aussi bien que le projet de l'UNESCO M.A.B. (Man and Biosphere) recherchent run et l'autre la conservation et la valorisation des ressources naturelles

---

(1) adresse : Secretariat Phytotronique

C.N.R.S. Phytotron, 91-Gif-sur-Yvette-France.

et ('optimisation de la production vegetale, ins Phytotronistes qui savent que les "moyens phytotroniques" sont des outils indispensables au progres de is plupart de relies recherches, se declarent prets a "consid6rer" tout programme, probierne de cooperation ou de coordination qui pourrait leur etre propose par le P.B.I. ou par le M.A.B. ou autrement et dans un tel but.

* *

L'optimisation de la production globale de la photosynthese et set bases ecologiques et physiologiques etaient le sujet d'un symposium international prevu par le P.B.I. en deux parties, Tune a Trebon (Tchecoslovaquie), l'autre a Moscou (U.R.S.S.) toutes deux rune apres l'autre en septembre 1969. La simulation ou la "model isation" mathernotique des problemes y fut envisagee. A ('issue de ce double symposium, c'est-e-dire le 29 septembre 1969 a "Am., tout ce qui precede a etc rapporte et a reteeu un vif interet de Peesemble des participants a ce symposium : une cooperation des Phytotrons aux problemes d'optimisation de la productivite des plantes et aux expressions mathernatiques de ces problemes est apporue commie hautement desirable.

⁂

Pour les services qu'on peut en attendre les Phytotrons et les equipements phytotroniques doivent etre exacternent adaptes a leur finalite propre, differer selon les problemes a trailer et selon les circonstances, perdre la reputation erronee d'etre trap elicit et ne co0ter que ce qu'il foul pour le but recherche. C'est encore une question de technologie confront & avec les divers besoins de l'Ecophysiologie. C'est ce qu'a voulu exprimer le Professeur F.W. WENT a la fin des reunions de Phytotronique a Seattle et qu'il a transcrit dans la courte note suivante :

PHYTOTRONS .- " My experience with phytotrons has shown that one of the most important conditions in " their establishment is the collaboration with a fully competent engineer. Most oir con"'ditioning engineers have had no experience with the controlling of the greenhouse en" vironment and consequently grove errors have been made in construction of a number of " them. I would suggest that o list of engineers be prepared who have had experience in " building air conditioned greenhouses before one is employed to design a new one. This " not only will affect the operation of the greenhouses, but also its operability and eco" nomics.

" If one calculates the total cost of ❑ phytotron and divides this by the total area " available for the growing of plants, then the only 2 installations which I know of where " the building and installation costs were less than $ 100 per square foot are the Earhart Plant Research Laboratory and the small air conditioned greenhouses and artificially lighted rooms at the Desert Research of the University of Nevada System, which were $ 90 and $ 80 respectively. The actual cost of the phytotron is largely a Function of the " degree of control which can be exerted. Whereas, it is essential to have somewhere an " installation where the control is very precise, such as in the phytotron in GiF, for most " work a lower degree of precision is not only acceptable, but advisable. It still has to be " shown to what extent control of the relative humidity is essential for controlled plant " growth.

" Although it would seem obvious from the results obtained in the different existing " phytotrons that environmental control is essential in the growing of plant material and " in studying plant response, it is still to often claimed that such control is too expensive. " I completely disagree with the latter statement. It also should be mentioned the use of " uncontrolled environments in plant experiments is unreasonably expensive in terms of inef" ficiency and waste of the time of researchers.

" In the greenhouses which we are operating now in Reno, it has been found that " a number of plants could not possibly be grown in one, although they thrive in another " greenhouse, because of their special temperature tolerance. Cyamopsis, an Indian legu" me, for instance, does not grow at all at cooler day and night temperatures, whereas, " it thrives at 30° day and 20° night temperatures provided they are subjected to a long " day. These are the same conditions under which some of the desert plants, for instance, " Lorre° thrive, whereas, other typical desert plants such as Atriplex hymenelytra grow " best at 20° day and 10° night temperature. Under the latter conditions also a number " of montane herbs grow well, whereas, all alpine plants we tried grew best at 10° day " and 5° night temperature."

F.W. WENT
(Septembre 1969).-

⁂

Nous remercions tous les auteurs qui ont fourni les articles du present volume "Phytotronique I", tous les phytotronistes qui ont anime les discussions et qui sont entres dons la voie d'une cooperation ouverte, libre et féconde.

P. Ch. et N. de B.

Gif-sur-Yvette -91 France.
20 Octobre 1969.

INTRODUCTION

Par

Prof. P. CHOUARD - Faulte des Sciences - Paris
et Phytotron, C.N.R.5., Gif-sur-Yvette.

Je voudrais d'abord remercier toutes les personnes presentes a cette "Table Ronde" ainsi que celLes *qui* nous ont aides dans ('organisation de cette reunion internationale et en premier lieu l'UNESCO.

L'UNESCO s'interesse actuellement aux Phytotrons dans le cadre de son theme d'action dans les "regions arides". L'Assernblee Generale de ['UNESCO a, en effet, adopte dans ses resolutions la recommendation d' "agir en vue de faire progresser les connaissances scientifiques et leers applications en contribuant au developpement de la methode de maihrise de l'environnement par l'emploi des Phytotrons". 11 est probable que le champ d'intervention mointenant limite aux "zones arides" sera etendu a d'aurres sortes de regions "en voie de developpemeat" ou aussi a des problemes scientifiques fondamentaux *et* generaux tell que le theme du "programme biologique international *en* vue du bien-etre hurnain" actuellement prepare par l'Uniqn Internationale des Sciences Biologiques.

De toute fawn pour ('instant, c'est precisement porce *que* les Phytotrons peuvent cider a l 'amelioration de la productivite en Agriculture, par exemple dans les pays en voie de deveioppement, qu'il a ere possible de faire inserer un petit budget 6 la conference generale de ('UNESCO. Et &est precisement ce petit budget qui m'a permit de vous inviter b participer a cette "Table Ronde" et d'assumer les cfepenses relatives a certains deplacements ainsi qu'a l'hebergernent dont nous beneficierons a Connaught Hall.

Ce precedent inscrit a l 'UNESCO pourrait devenir le point de depart de possibilites meilleures et de perspectives pour l'avenir telles que :

1- L'envoi de stagiaires en provenance des pays en voie de diveloppernent er, quond ils seront entraines, ('assistance a ces pays pour requipement de mayens phytotroniques plus ou moins simplifies et appropries leurs besoins de recherches pures et appliquees.

2- Des reunions de F'llytorronistes en vue d'etudier en commun des problernes scientifiques et techniques relevant des methodes de mattrise de l'environnement.

3- La stimulation de recherches concertees sur les bases scientifiques de Ia connaissance de la croissance et du developpement et, finalernent, de tout ce qui constitue les bases de Ia productivite des vegetaux.

Nous pourrans, au court des presentes reunions, discuter er exposer not points de vues sur les formes de cooperation possible et peur-letre, ici ou plus tard, proposer un programme plus vaste et plus concret a ('appreciation de ('UNESCO.

Mais aussi je voudrais tres simplement remercier les quelques personnalites eminentes qui ont bien voulu se charger des debuts et cel les qui ant bien voulu preparer des exposes a entendre eta discuter.

a
o o

Avant de laisser to parole aux conferenciers, je voudrais disserter brievement sur les definitions de mots propres a ('objet de notre rencontre ; ils sont en gronde pantie empruntes aux Prof. A. LANG, avec quelques nuances ou modifications de mo part.

On vo parler des Phytotrons et de Ia Phytotronique. Mais qu'est-ce qu'un Phytotron ? Qu'est-ce que la Phytotronique ?

Je n'insisteroi pas sur l'etymologie du mot Phytotron, issu d'obord d'une plaisanterie (cyclotron

phytotron) mais qui, d'apres un helleniste de mes arnis, pourrait egalement signifier : "tirer de la plonte tout ce qu'elle peut fournir par les moyens et par les artifices de l'homme", ceci par reference au mot grec Arotron, le charme de l'araire, instrument pour tirer du sol tout *co* que l'homme peut en faire sortir.

Pratiquement, pour nous, it semblerait que Ion puisse appeler Phytotron tout instrument, ou pleat tout equipernent dans lequel on peut maitriser plus ou moins completement plusieurs facteurs de l'environnement simul tenement et separement. Plusieurs, car s'il s'agissait d'un seul facteur, taus ceux qui ont par exempla une etuve ou une serre diraient qu'ils ont un Phytotron. Je crois qu'il n'y a pas de Phytotron s'il n'existe pas plusieurs combinaisons de ces divers facteurs *du* milieu. La Ida it y a une seule combinaison permanente de plusieurs facteurs

du milieu, c'est seulement une unite d'un Phytotron. Celui-ci, en effet, doit etre forme de plusieurs unites pour permettre d'assurer non seulement la reproductibil itid'une experience dons une situation elle-meme bien reproduite, mais aussi de combiner des experiences comparatives indispensables a Ia logique meme de 1' experimentation physiologigue selon laquelle sont eprouvees les valeurs diverses dune meme variable, toutes les autres variables etant fixes, celles dune autre variable, etc.., et enfin les combinaisons de deux, puis de plusieurs variables simultanement, les variables etont ici chacune des composontes de l'environnement.

On pourrait donc definir un Phytotron en un !engage plus moderne ensemble de modeles redulls de climats et d'environnements ou,encore, des simulateurs de climats et d'environnement ou des simulateurs de types de culture_ De meme que les avioteurs 00 des simulateurs d'avions en vol pour pouvoir prevoir tout ce qui se passera durant tin vol reel -de mime avec un phytotron nous cherchons ii simuter des conditions naturelles complexes en les reduisant a des combinaisons simples et defines de fawn a connaltre ce qui se passe dans chacune et essayer de prevoir les reactions dans les conditions naturelles plus complexes.

I I y a, naturellement, toute une gamme de possibilites de construire ou de realiser des phytotrans fort divers repondant a cette definition generale du mot phytotron. I I y en a des grands ou des petits, les dimensions des locoux phytotrones n'importent pas d la definition ; par exemple, on peut avoir un groupe de petites bones bien conditionnees, un group. de petits cabinets ou un ensemble de grandes solles climatisees. Recemment, j'ai entendu parler d'un projet ou cheque salle devroit avoir un volume de l'ordre de 10.000 et meme de 100.000 metres cubes mais, bien set-, ce projet n'est aucunement celui de botonistes

Le nombre de facteurs martrises a la fois peut etre egalement different: 2,3,4) temperature et lumiere en duree, ou bien aussi lumiere en niveou et en qualite d'eclairement, humidite, nutrition minerole, teneur de lair en gaz carbonique, etc... De meme le degre.de precision dons le contrele de ces facteurs peut etre different. Tout calm constitue mutant de types de Phytotrons qui ont chocun un but et un usage porticuliers ; I run d'entre eux peut convenir exactement 6 certaine recherche et ne pas convenir du tout d une outre recherche. De sorte qu'il n'y a pas de phytotron que Ion puisse dire a la fois parfait et bon "a tout faire" ; plus les services demand& a un phytotron seront divers, plus la perfection sera difficile a approcher. Ce qui peut approcher de la perfection, c'esr Ia specialisation d'un phytotron pour un but determine. Cela n'empeche pas qu'il y ait une definition commune tous, un effort technologique commun, un "savoir faire" commun, en un mot, une "phytotronique".

o o o

Voici done ce mot plus nouveau, la "Phytotronique", que je vous propose d'adopter :

Il est cree par analogie avec les mots (employes ici comme substontifs) :
- "Electronique" -science des electrons, des phenomenes qui les concernent et de leur emploi.
- ''Hydroponique" -science de la culture oe ['eau, et non le sol, est le principal moyen d'intervention. -
"Physique" (au sans large) -science de la nature.

Le terms "Phytotronique" peut designer dune maniere ossez large et comprehensible tout ce qui se rapporte aux Phytotrons, consideres comme instruments a savoir utiliser, i5 perfectionner et a adapter, comme outils de travail pour un ensemble coherent de problemes de science pure et de science appliquee dont it convient de confronter l'avancement.

C'est dans ce sens qu'il avait etc employe, semble-t-il, au cours des deux colloques qui se sont tenus l'un a Canberra en acid 1962, sur les problemes scientiFiques de physiologie vegetale qui relevant des moyens de maitrise de l'environnement, l'autre a Melbourne en septembre 1962, sur les techniques de maitrise de l'environnement, c'est-e-dire precisement sur la realisation des dispositifs et sur l'agencement des phytotrons.

Pour le moment la phytotronique nest pas une science en soi ; c'est une technique appliquee k science, mais une technique qui devient de plus en plus importante et qui, peut-etre, un jour, deviendra une science. Une certoine analogie avec l'evolution de ce qui &ail' et ce que devient l'electronique est concevable. Actuellement rifle un grand nombre de personnes s'y interessent ; jugez-en d'apres noire nombre d'aujourd'hui et ici, &ors que nous ne sommes pas le tiers de ceux qui nous ont fait part de l'interet clu'ils portent b notre programme.

L'interit augmente partout pour les moyens, les methodes d'asservissement de l'environnement et la "physiologic de l'environnement". Celle-ci devient en verite l'un des aspects les plus importants de la physiologic moderne. Pour cela, T1 1ut foul des outils appropries ; les Phytotrons sont ces outils. Nous ovons a cooperer ensemble at c'est ce que nous allons essayer de faire en discutant des divers aspects de la phytotronique.

⁂

IS THERE A BASIC COMMON DENOMINATOR IN ALL PHYTOTRONS ?

by

Dr Dov KOLLER

Department of Botany, The Hebrew University, Jerusalem, Israel.

I asked to rake the subject of the common denominator before this Symposium because all phytotrons which I have seen or read about differ from each other. As a result of this great diversity amongst phytotrons, anyone who contemplates building a phytotron today has to make a thorough study of all existing ones, evaluate the merits and shortcomings of each, combine to the best of his judgment the most favorable features of all, and add several original contributions to the design. If he is careful, he will also test his overall design in a "pilot-plant" phytotron. This procedure is most educational for the future phytotronists, and will most probably lead to genuine advances in phytotron design and operation. It is, however, prohibitively expensive for most scientific institutions, as well as time-consuming to scientists who merely need the phytotron as a tool of a range, accuracy and versatility to be determined by the general area of research and the size of their budget.

Diversity amongst existing phytotrons has come about in several ways.

The diversity due to lack of an agreed definition of a phytotron, has already been adequately **dealt** with in the opening remarks by Prof. Chouard. Some diversity arose through the scientific and technological evolution of phytotrons, with our increasing understanding of the alert and its environment and with the improved technology at our disposal. This evolutionary process will and should undoubtedly continue to produce newer and better "models" of phytotrons. An additional cause of unavoidable diversity is the specialized nature of the problems which some phytotrons are exclusively devoted to, i.e. special crops (sugar-cane, lice, forest trees, fruit trees), epidemic diseases, special environments, etc... There are, however, two avoidable causes for diversity. First, lack of agreement among phytotronists on the relative value of various environmental factors for critical experimental work, and second, the different interpretations which the designing engineers have made to the requirements spelled out by the biologist. It is my hope that this conference, coming as it does after about 20 years of experience with phytotrons, may help to correlate the accumulated knowledge and thus clarify the issues involved, so that common basic features of "normal" phytotrons can be indicated. Let me make clear that by "common denominator" I do not mean prefabricated phytotrons or even a standard plan, since clearly size, range of conditions, degree of accuracy and versatility, allocation of space for darkness, artificial light and natural illumination, will all be determined by requirements of climate and budget.

in trying to define some of the properties of the common denominator in phytotrons one should start with an **agreement** of the concept of a phytotron. A phytotron may be described as an "environmental spectrograph", which can simultaneously provide a relatively large number of different environments, in a more or less continuous spectrum. It differs basically from a spectrograph, however, since the latter deals with but one variable (wavelength), while the variables which make up the plant's environment are numerous. The utopian phytotron should, in theory, provide the possibility of simultaneous testing of plant responses in a multifactorial environment, covering all environmental factors known to biology. The utopian phytotron is therefore an unrealistic and probably unmanageable monstrosity. The compromise solution is to provide "permanent" gradients for a limited number of factors and make adequate provision for introducing "temporary" gradients for as many of the remaining factors as is practicable. In most phytotrons, the two factors provided as permanent crossed-gradients are temperature and light/ dark. Temporary gradients of daylength and light intensity are easily superimposed, the first by programmed light-dark shifts, the other by shading. Provision can possibly be made for similar temporary gradients of other environmental factors, to be "piped in from some central supply to each compartment of the existing permanent gradients. For example, if hot and cold water ore piped into all compartments, suitable mixtures con be run through heat exchangers to provide different soil temperatures. Similar arrangements can possibly be made to supply air of different gaseous composition, humidity, etc.. To accommodate these temporary gradients, versatile small sub-compartments should be made available, the contents of which are isolated from these of the main compartment, with respect to the factor which is varied in the temporary gradient.

An additional prerequisite of phytotrons is uniformity of the environment. The plant environment within each compartment is uniform if mass and energy are evenly distributed. In the aerial environment of the compartment, even distribution of mass and kinetic energy at the plant surfaces can be achieved not only by ensuring uniformity at the source, but also by reducing resistance to boundary layer diffusion at the plant-atmosphere interface, which can only be done by increasing wind velocity. Selection of the appropriate method of air movement -floor to ceiling, wall to wall, or turbulent mixing- would depend on the topography of the plant canopy within the compartment, since mutual interference with air movement between neighboring plants would differ in each case. Even distribution of radiant energy requires uniformity of the source, as well as avoidance of mutual interference by neighboring plants. Ample spacing between individual plants, and between walls and plants is the obvious answer, but frequent randomization of the population within the compartment should also be practiced. It should also be kept in mind that radiation from artificial light sources changes with lamp age, while that in naturally-lit compartments changes with season. Provision should therefore be made for programmed replacement of lamps in the first case, and caution should be used in comparing results obtained in different seasons in the latter case.

if temperature is taken as the main permanent gradient, all other factors should be kept comparable in all compartments. With respect to light, this implies a similar orientation of all naturally lit compartments towards the sun, and equal lamp temperature in the artificially lit compartments. CO_2 concentrations can be kept comparable in the different compartments, and free of daily variations, only if maintained at a level equal to, or higher than the maximal produced by plant respiration in darkness. Of all humidity parameters, the most significant one for the plant is the vapor pressure gradient between leaf and air. Since saturated vapor pressure varies with temperature, it is not sufficient to maintain atmospheric humidity ar a constant level, but air movement should also be kept sufficiently rapid to minimize the temperature differential between leaf and air. Furthermore, by the same reasoning, it is obvious that comparable vapor pressure gradients in compartments maintained at different temperatures are limited on the one hand by the minimal humidity which can be maintained in the coldest comportment, and on the other hand by the disease-promoting action of high humidity. Finally, irrigation schedules have to be worked out, taking into account the different rates of water loss through evapo-transpiration under different environmental conditions.

The last aspect I would like to touch upon is that of flexibility. Only too often are phytotrons rigidly designed to accommodate just the present requirements of research at the institution. Additional rigidity is superimposed by basing the design on sizes and capacities of existing lamps, machinery and equipment. This rigidity leaves little scope For changes, to accommodate new interests and improved equipment. Flexibility of use may possibly be achieved by dividing the entire controlled space along the permanent gradient into the smallest practicable compartments. If each of these can be regulated over a certain limited range, increased demands for space in any one condition may be satisfied by reallocation at the expense of other conditions where pressure is lower. Requirements for special, isolated conditions can also thus be met, and entire compartments set aside as required, for studies in special temperature regimes, spectral regions gas mixtures, pathological, entomological, or radioactive work, etc. Such an arrangement will facilitate routine maintenance and repairs, since only small portions of the installation will be shut down at any one time. Moreover, this will permit economical operation, by closing down space which is not in use. Finally, flexibility in technical design should be achieved by allowance of space for future installation of different-sized lamps and conditioning equipment, additional cooling and heating capacity and more pipes, ducts. and conduits.

I do not presume to hove exhausted the subject, but have merely tried to scratch the surface, in the hope that the following talks and discussions will enlarge on the subject and help us obtain a better insight into the common denominator in all phytotrons.

0
00

SCIENTIFIC AIMS OF THE PHYTOTRON OF READING

by

Dr A.P. HUGHES, A.R.C. Unit of Flower Crop Physiology,

University of Reading.

In our work we are attempting to provide basic physiological information to enable the glasshouse growers in this country to improve and diversify their products, particularly of flowers, either cut or in pots, during the winter months when the days are as short as eight hours and light intensities are very low. We ore interested, therefore, in the relationships between light, temperature, carbon dioxide concentration and day length, and it is essential for this to have a multifactorial system of investigation. Furthermore, after we have resolved these in more-or-less constant conditions, we need some outside conditions in o glasshouse to confirm that the results of the cabinets can he extrapolated to commercial conditions. Our facilities consist of a hall which contains nine cabinets with provision for o total of twelve (fig. 1), enabling us to carry out a 3 x 2 x 2 factorial. We have also in construction a four compartment glasshouse with automatic daylength control, the plants being brought out during the daytime on trolleys and returned at night to a dark garage in which appropriate day-length extensions or night breaks can be given. This runs at right angles to the south end of the cabinet hall.

Fig. 2 and 3 shows the arrangement of the cabinet hall and ancillary rooms. The hall has forced ventilation to remove the excess heat from the light housings on each cabinet. Air used for this ventilation is filtered free of dust and there is space in Front of the entry grill for installing a chemical filter should this be necessary. During the winter this warm air is used to heat the other rooms. The glycol (1°C) used for chilling the cabinets is itself cooled by a pair of water-cooled refrigerators, either of which is able to deal with two-thirds of the normal requirement.

The cabinets are based on the design developed by the National institute of Agricultural Engineering (1,2) and the illustrations are by the courtesy of the N.I.A.E. The plant space is entirely separate from the lamp housing and is sufficiently gas right to permit the use of carbon dioxide concentrations other than atmospheric. Alternatively dampers can be opened allowing up to 7 changes of air with the outside. Fluorescent tubes are specially arranged to give very high intensities with facilities for programming half the lamps thus : Day, Day and Night Break, Night Break, Independent Day, Day and Independent Day, Spare for emergency use (3). Some of the tubes can be replaced by long thin rows of tungsten lamps, fitting into the place of the fluorescent tube. These light controllers enable, for example, plants to be grown in white light and given a red far-red reversal treatment during the night period.

The total floor area of a cabinets is 20 sq.ft., there is an area of 16 sq.ft. (1.7 m^2) over which the extremes of light intensity differ by less than 5 %and the working height is about four feet. The maximum light intensity at floor level is about 0,2 cal/cm2/min (14 m W/cm2 or about 3,000 f.c. white light). Temperature can be controlled in the range 5-30°C with independent day and night levels. Humidity is controlled by dew point cooling, the actual minimum values depending on the dry bulb temperature viz. 7°C 80 % R.H., 13°C 60 %, 18-30°C 55 %. We have a system of sub-irrigation using plastic coated troughs into which the irrigating solution is pumped several times a day. Alternatively the troughs can be used as the basis of a capillary bench.

he maximum power consumption of a single cabinet and its refrigerator (excluding ventilation of building) is 13 KVA. The total consumption of our installation is about 200 KVA which makes it extremely expensive to have a standby generator. For the whole load, we are planning a smaller standby of 10 KVA to enable the cabinets to be kept in the same diurnal photoperiodic rhythm and to maintain all the monitoring equipment, which comprises continuous recording of temperature, light and carbon dioxide concentration in all cabinets.

REFERENCE .-

1.- Morris, L. G. , "Design of growth rooms", Control of the plant environment. Butterworth's, Sci. Publ. 1957,139.

2.- Carpenter, G.A., Maulsley, Li., "Artificial illumination of environmental control chambers for plant growth". J. Agric. Engng. Res., 1960, 5, 283.

3.- Carpenter ,G.A , Moulsley, L.J., Cottrell, P.A. ,Sumrnerfield, R., "Further Aspects of the Illumination of plant growth chambers". In the press.

DISCUSSION .-

Prof. Lang : Can you tell us what is the working space for plants and the price of one of your cabinets ?

Dr Hughes : The working area is 20 sq.ft. (x) and the cost when available commercially is likely ro be E 2,500 - 3,000 including the chilled glycol system.((x) 16 sq.ft. within 5 % of maximum light, 20 sq. ft. within 10 %of maximum).

Prof. Lang That **is almost 10, 000** dollars. in the United States you can buy rooms which, as far I can tell, perform at least most of your jobs for the price of approximately 200 to 250 dollars per sq.ft., which works out at about 4,000 dollars. After what Dr Kohler said this would be a case where I would be wondering myself whether this effort would be really justified.

Mr Morris :I would not agree with Prof. Lang that the rooms to which he is referring do the some as our cabinets. it is possible to design a cabinet which looks very much like the ones illustrated for half the price or less. The cost is the result of the range of control provided, the intensity of the lighting and the accuracy of control. I da not believe any room can have as good control as the cabinets at the same price.

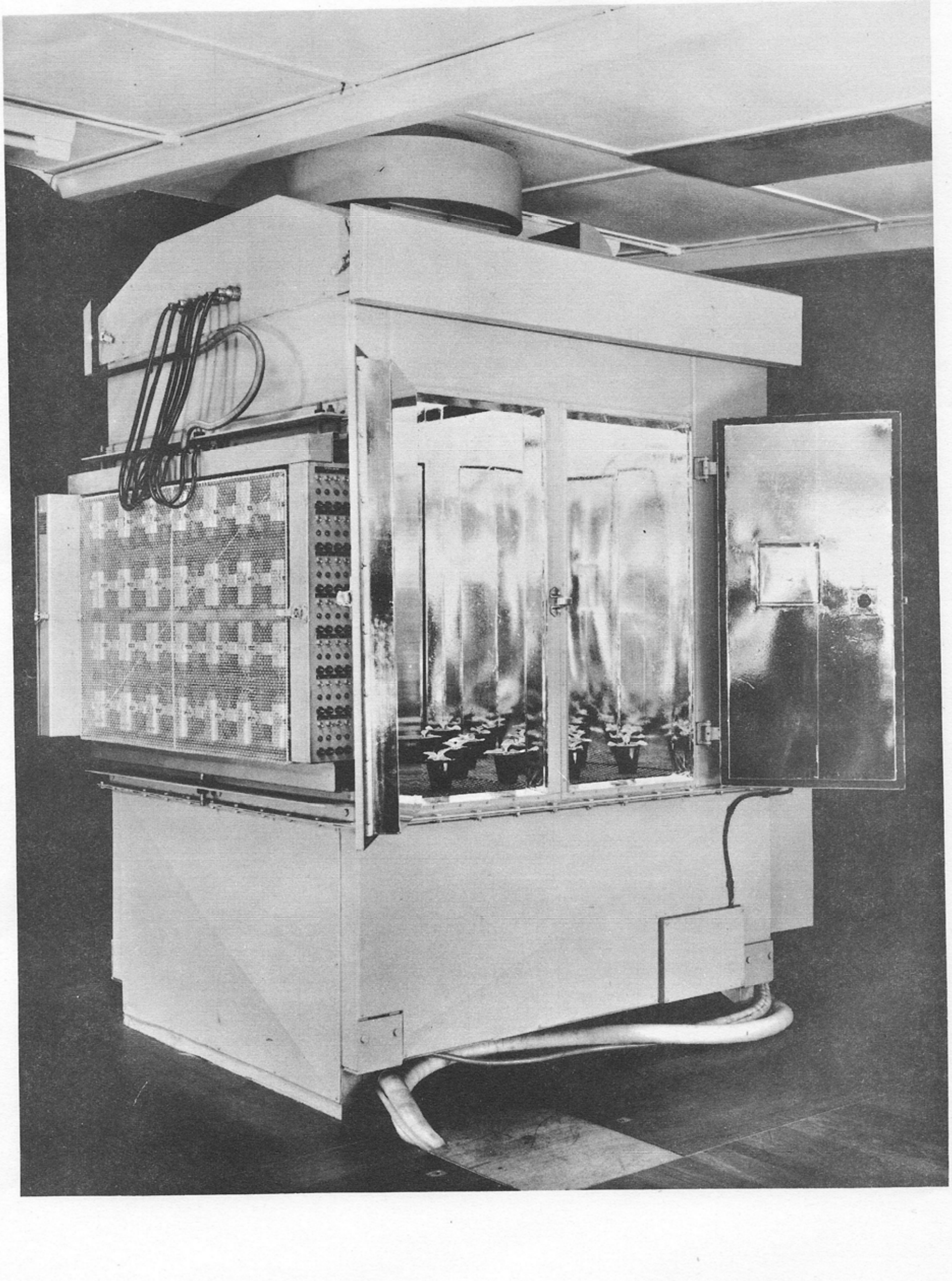


Fig. 2.- Cabinet based on the design developped by N.I.A.E.

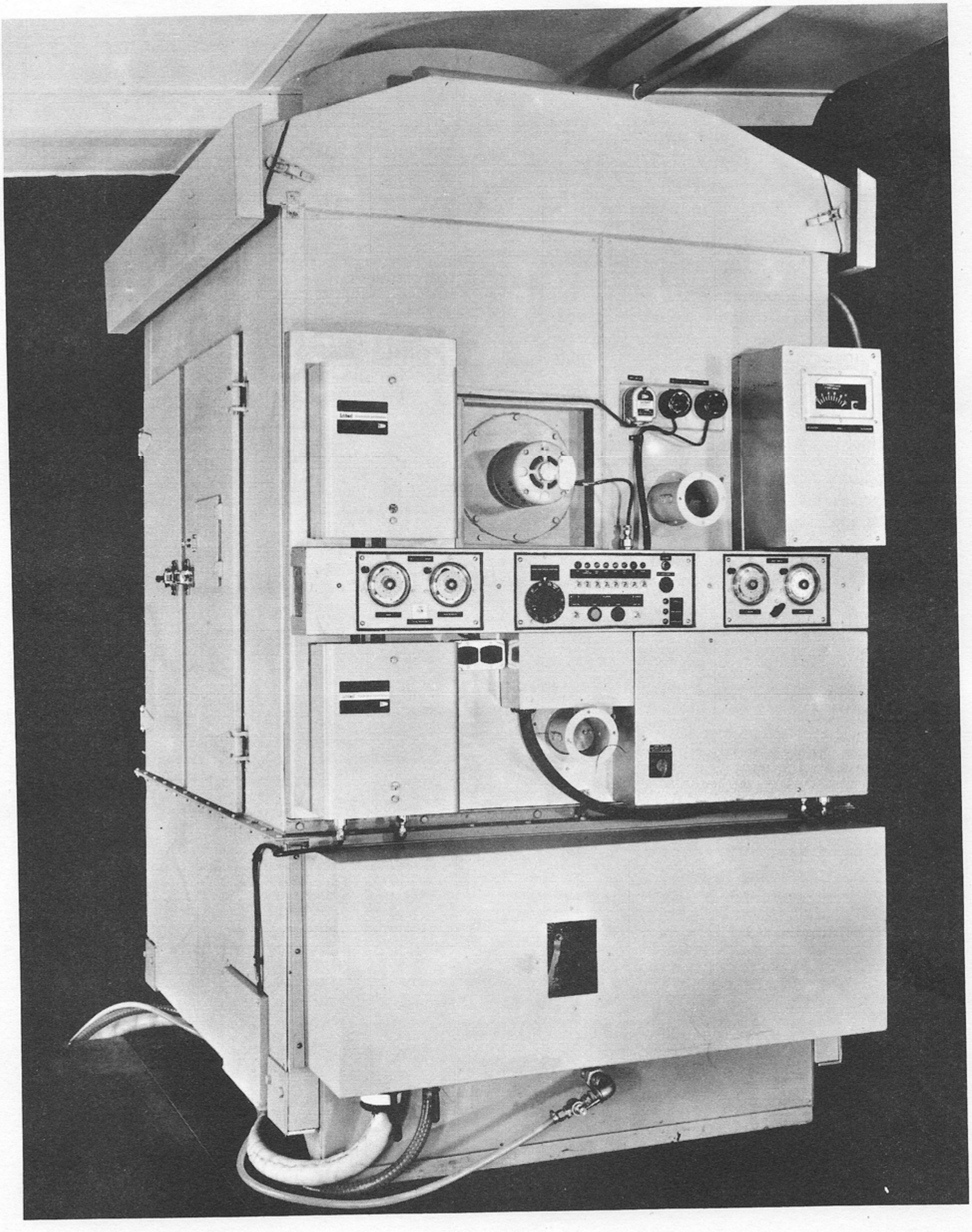


Fig. 3.- External view of cabinet N.I.A.E.

THE PHYTOTR ON OF THE LABORATORY OF HORTICULTURE OF THE STATE AGRICULTURAL COLLEGE, WAGENINGEN ,Netherlands.

by

Dr J. DOORENBOS, Laboratorium voor Tuinbouwplantert4elt - Wageningen.

The Phytotron of the Laboratory of Horticulture at Wageningen (fig. 1) has been planned to study the effect of the environment in growth and development of horticultural plants, e.g. tomato, apple, carnation and tulip. This made it necessary to construct rather large chambers. The Phytotron comprises six air-conditioned greenhouses, each with a surface of 5 x 5 m, six growth chambers of 6 x 4 m,and a height of 2,5 m, and six dark rooms of 4 x 4 m (fig. 2). in each room, temperature and air humidity can be controlled. Ten times per hour, all air is replaced by outside air. It is not possible to control the CO_2 content.

The air flow (onenaverage, 60 cm/sec.) is horizontal. In the greenhouses, it enters through a slit along the Eastern wall, about 60 cm above the floor, and is removed through a similar slit along the Western wall. In the other growth chambers, the air enters through the whole of the Eastern wall and is evacuated through the opposite wall. Both walls are covered by adjustable shutters (fig. 3).

The rooms are at the moment kept at 9, 12, 15, 18, 21 and 24°C, in such a way that one greenhouse, one growth chamber and one dark room is kept at each of these temperatures. Other temperatures are of course possible. Each room has a constant temperature ; if a night temperature is required that differs from the day temperature, the plants are removed to another room. For this purpose, the plants will be grown on trolleys_

The growth chambers are illuminated by 400 fluorescent tubes of 40 Watt, which give a light intensity of 17.000 tux (52.000 ergs/cm^2, sec) at bench height (or 21.000 lux at 50 cm below the ceiling). Philips TL 55 was chosen as this type emits an appreciable amount of far red.

The lamps have been installed in an atrium above the growth chambers, from which they are separated by a glass ceiling. The frames can be raised 1,5 m to allow substitution of lamps and cleaning of the glass panes. In this purpose, a trolley with room for two technicians can ride over the glass ceiling under the raised lamp frame (fig. 4). Once every three months one fourth of the fluorescent tubes is substituted by new ones.

The hot air around the lamps is evacuated by six ventilators, one for each frame. These are thermostatically controlled. The fresh air coming in from the outside passes through filters which sieve out dust and insects. There is no chemical air pollution in Wageningen.

The temperature in the six air conditioned greenhouses can be controlled within the same ii. mils as in the growth chambers. On sunny days in summer, however, they cannot be kept below 15°C.

Every room has its own airconditioning equipment, which has been installed in the cellar. The air is cooled by expansion of Freon (except in the case of the three rooms at 24°C, where the air is water cooled). It is moistened by blowing it over the surface of water, the temperature of which controlled by a thermostat. All equipment operates by electricity. The Phytotron uses about 2.2 million kWh annually. For the Phytotron alone, a transformator of 600 kVA had to be installed.

DISCUSSION .-

Wolff (Vienna) What is the capacity of your cooling machine ?

Doorenbos : This variesfrom 11.500 to 13.000 kcal/hour (dark chamber) 15.000 to 24.000 kcal/hour (light chambers) and 27.000 to 33.000 kcal/hour (greenhouses).

<u>Orchard</u> (U. K.) : How uniform are your temperatures ?

<u>Doorenbos</u> They are supposed to be + 1°C, but it is too early to say with certainty that we can reach this in each room at every temperature.

<u>Orchard</u> (U.K.) :What range of humidity have you ?

<u>Doorenbos</u> : Range of humidity control was one of the things we had to sacrifice if we wanted large sized rooms. All rooms are now kept at 70 %. We found that we can go as high as 80 %, but not higher. A lower humidity than 70 % is of course easily obtained.

⁂

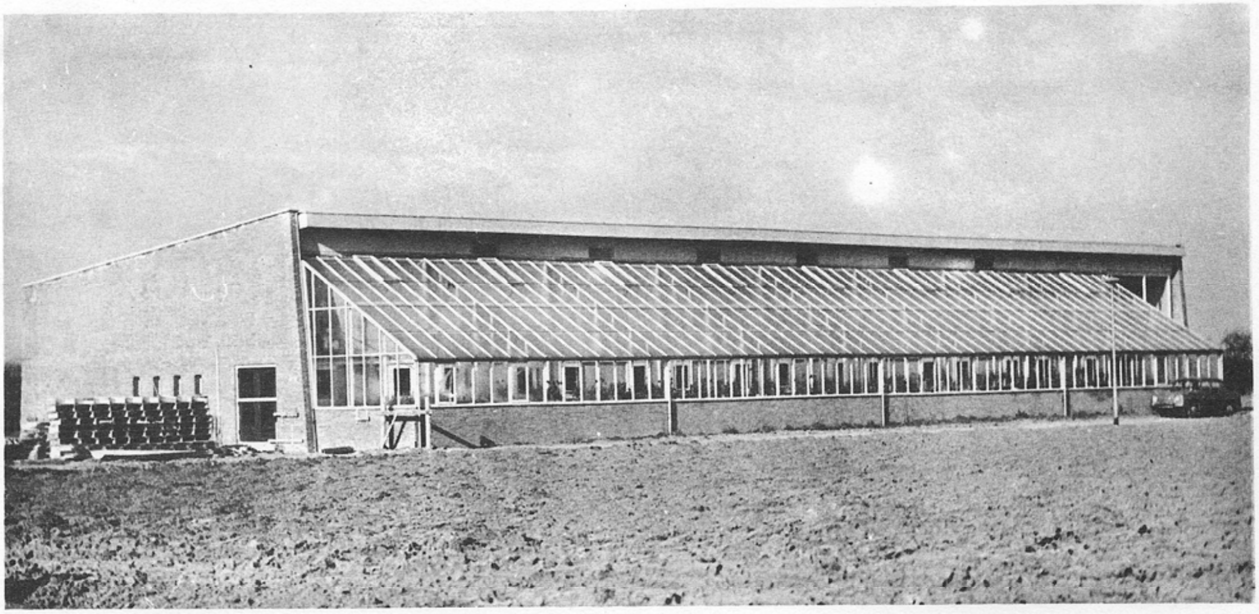


Fig. 1.- The Phytotron of the Laboratory of Horticulture at Wageningen from the South.

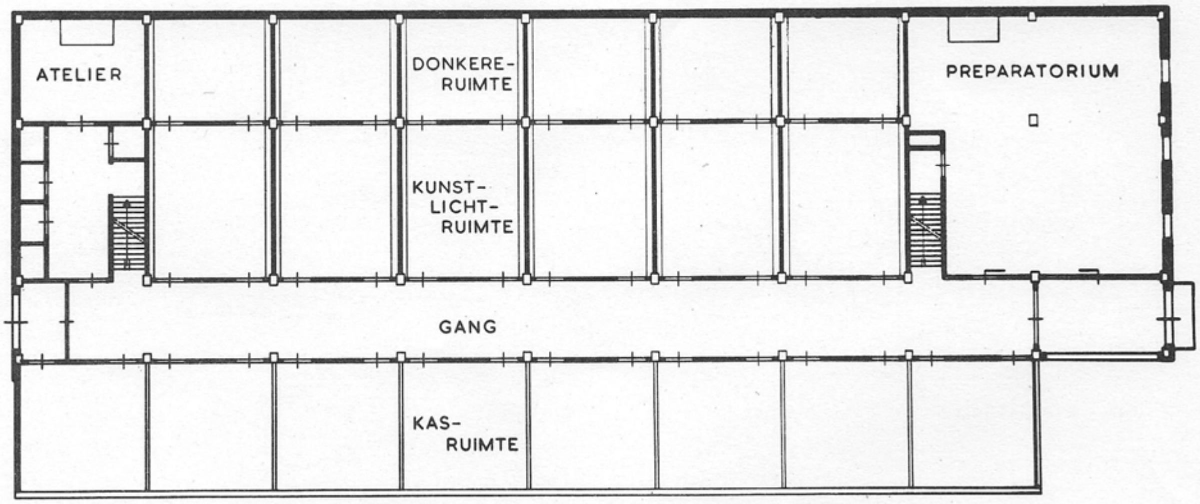


Fig. 2 .- Groundplan of the Phytotron, showing the six dark rooms ('donkere ruimte'), the six light chambers ('kunstlicht-ruimte') and eight greenhouses ('karsruimte'), six of which are air-conditioned.

Fig. 3.- Part of a growth chamber. The air enters through the right wall and is evacuated through the left wall. The doors at the back give access to a dark room. In the future, plants will be grown on trolleys.

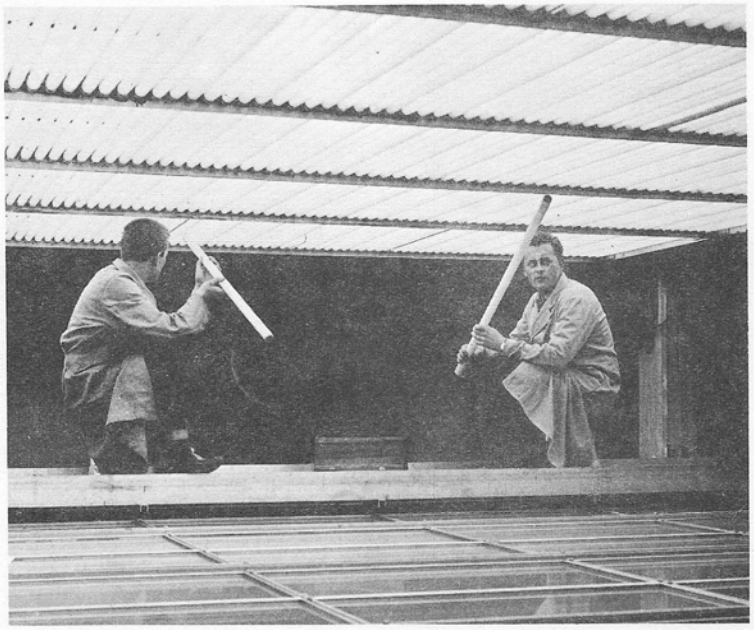


Fig. 4 .- The lamp frame has been raised to permit handling of the lamps. The technicians sit on a trolley that rides over the glass ceiling of the growth chamber.

NEW CLIMATIC MEASURING CHAMBERS FOR PLANT PHYSIOLOGICAL RESEARCH

INTRODUCTION

by Prof. Gertraud REPP, University of Vienna .-

Permit me to introduce briefly a paper to be presented by M. Wolf, a physicist who collaborated in the development of a new type of Phytotron constructed in Austria.

I myself am a plant physiologist, my field of concentration being experimental ecology, today also known as "ecophysiology". As ecophysiological field work is difficult in view of the often very extreme climatic conditions involved, climatic chambers and phytotrons as developed in the recent past ore highly valuable tools facilitating our work. These chambers render possible exact muttifactorial experiments designed to study the ecophysiological response of plants to environmental conditions, even if these conditions are as extreme as are encountered in deserts or at the timberline of high mountains. However, the discussion regarding the type of climatic chamber best suited forpracticalwork still continues : will this be the large phytotron permitting the scientist to walk in and carry out his experiments or a small chamber designed to house the plants only, which is cheaper in operation and easier in handling ?

Due to the invention of the infrared absorption writer (Liras), the ecophysiologist today has at his disposal an excellent self-registering instrument for taking rapid measurements of the transpiration and the assimilation, and consequently of the production of plants in relation to their environmental conditions. To carry out these experiments, however, it is necessary to enclose the **plants or** at least part of them in a socalled "cuvette". The climate in these small "cuvettes" differ widely from the open air conditions under which the plants normally grow. Hence the problem of the "cuvette climate" still occupies the center of discussion among ecophysiologists.

Austrian physicists attempted to find a solution covering both of these problems by developing small climatic chambers in which the plants not only can grow, but in which, with the help of the infrared absorp- . tion writer, the assimilation and transpiration of plants can simultaneously be measured at every individual stage of development. Consequently, these climatic chambers not only constitute a king of small climatized "growing room" (microphytotron unit), they also serve as measuring chambers rendering possible highly exact measurements.

With the help of these chambers numerous muttifactorial experiments can be carried out, on the basis of which data pertaining to the ecophysiological response of the plants to different environmental factors os well as to their resistance to extreme climatic conditions can rapidly be obtained.

The number of environmental factors to be controlled depends on the type of chamber used. So far two types have been developed under Hans Millendorfer, a physicist who started his work at the well-known Patscherkofel Research Center for the Reafforestation of High Alpine Regions (The Tyrol, Austria). His collaborator M. Friedrich Wolf will now outline the technical principles underlying these two types of climatic chambers, which -in my opinion- are a highly promising new development in the field of phytotronics.

TECHNICAL DESCRIPTION

by

Dr Friedrich WOLF, Vienna.

The phytotrons and climatized chambers available so far were only designed with a view maintair ina air temperature, air humidity, and light at determined values. After a longer period of growth the reaction of plants to these environmental factors is examined. Assimilation and transpiration are measured with the help of various methods available. However, we are today not yet in the position to determine the total CO_2 and H2O balances within a short period of time, e.g. he balances per hour, and simultaneously to provide for on exact regulation of all environmental factors involved.

It has been Felt than our knowledge of the plants response to environmental conditions will remain incomplete, if the range of variable factors is limited to include no more than ambient air temperature, air humidity, and light. Therefore, the RUTHNER PHYTOCYCLON was designed providing, in addition to the factors mentioned, for a control of wind velocity, soil temperature, soil moisture, and soil aeration (Fig. 1).

With the help of the Phytocyclon it has become possible to obtain data from assimilation and rranspira'io- measurements in a much shorter time without interfering with the defined climatic conditions of the plant and without destroying the plant itself by determining its dry matter yield.

Now to the RUTHNER PFIYTOCYCLON's theoretical Fun dotion and its technical data Sprout and root of the plant are treated separately in two closed climatic circuits, the sprout in the socalled "green zone" and the root in the "soil zone". There they are exposed to circulating air, whose H_2O and CO_2 contents can be measured separately as well. A defined air flow (L) with a CO_2 or H_2O water entrance concentration (5_0) is circulated through these two closed circuits, the entrance concentration being converted into the concentration prevailing within the measuring chamber (9) due to the assimilation, respiration (q), and transpiration (q') of the plant. The interrelations of these Factors are expressed by the following differential equation :

$$q = L\,(\varrho - \varrho_o) + V\,\frac{d\varrho}{dt}$$

V being the volume of the chamber in liters,

L the incoming fresh air,

ϱ the concentration of CO_2 in the test chamber,

ϱ_o the concentration of the incoming fresh air.

A special feature inherent in the design of all of the RUTHNER climatic measuring chambers is that the volume of the chamber, in relation to the incoming fresh air, is reduced to such an extent that it can, as a rule, be neglected during experiments. The equation is then reduced to :

$$q = L\,(\varrho - \varrho_o)$$

For <u>assimilation and respiration</u> measurements the CO_2 concentration of the fresh air as well as that of the air in the test chamber is continuously recorded. Diaphragm pumps feed samples of fresh air and of the

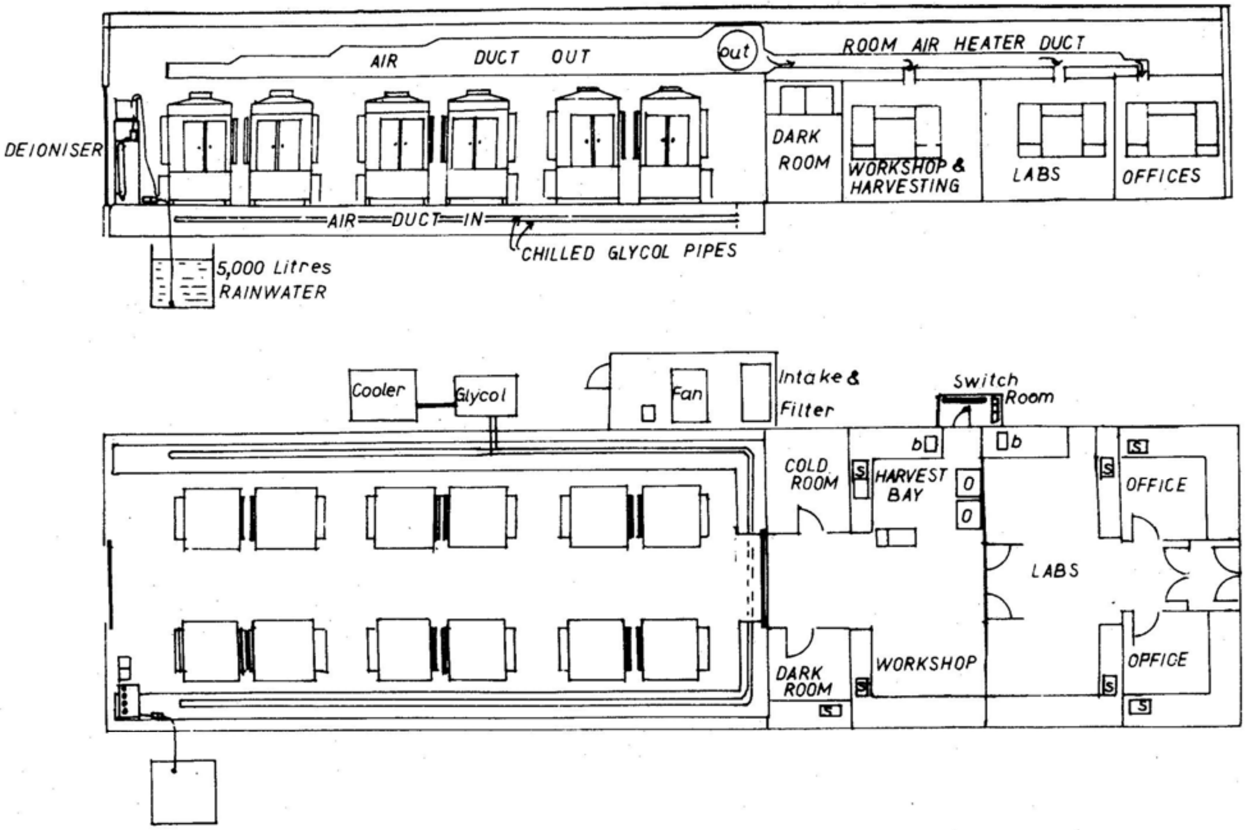


Fig. 1.- A.R.C. Unit of Flower Crop Physiology, University of Reading.

air in the chamber into the CO_2 gas analyser, which is connected with a 6-point-recorder.

The same process is applied to measuring the respiration of roots in the soil zone.

When evaluating the recorder tapes, the quantity of fresh air measured is taken into acount. Consequently it is possible to read the assimilation (or respiration of roots) on the recorder tapes in g/sec with the help of a special linear scale.

For measuring the transpiration the dew point of the air in the test chamber is continuously recorded by means of a dew point detector. In order to record the dew point of the air coming from a dry bypass, a second detector is included for determining the difference between these two dew points.

Evaluation is done in much the same way as for assimilation by neglecting V :

$$q' = L\ (\text{zet prime}' - \text{zet prime}_0)$$

q' corresponds to the emission of vapour in g/sec, this being a measure for transpiration,
L' being the measured quantity of the air circulating in the bypass,
zeta prime and zeta primeo indicating the absolute humidity at the front and rear end of a drier.

So far the theoretical foundation, and now the operational process involved :

The sprouts are introduced into "green zone" through apertures ensuring a gas tight closure. Two blowers provide for the ventilation of the green zone, which consists of two ducts, one duct being connected with the suction side of one fan and the other duct with the exhaust side of the second fan. This arrangement helps avoid the dead volume of the return ducts which is undesirable for gas analysis. Owing to a continuously variable speed control of the blower motors, any wind velocity up to 100 km/h can be obtained.

The dimensions of the green zone ore as follows :

length .... 2 m
width ..... 2 x 30 cm
height 50 cm

The air temperature of the green zone is regulated by a controller. Like all regulators, th...is controller is equiped with two dials providing for a day and night adjustment of temperature. Two 50..A.platinum resistance thermometers located at each end of the test zone serve as sensitive elements. The regulator controls a motor valve and an electrical heater in the cooling liquid circuit. The liquid passes heat exchanger units, which are located in the air circuit of the green zone and which, owing to their special design, operate at relatively low temperature differences. For all practical purposes this avoids loss of water in the heat exchangers. For controlling the humidity in the green zone a dew point detector compares the dew point of the air in the green zone with the regulated fresh air dew point. Via a measuring bridge and an amplifier this dew point detector actuates a control valve. The latter controls the

flow of air in a bypass, which air, by means of blowers, is passed over a refrigerating drier equipped with an automatic defroster.

The arrangements for the irrigation of the green zone are such that by pressing an irrigation key water, nutrient solutions, or plant protecting substances are spread into the plants through special nozzles.

The test chamber proper of the "soil zone" contains the pots or boxes for the plants. They are inserted through lateral openings, the sprouts being passed from the soil zone into the green zone through the upper diaphragm.

Physiologically, air conditioning the test chamber proper of the soil zone by means of blowers is of no importance ; it is merely required for climatizing the area. This air movement, however, must not be confused with the aeration of the soil itself, which represents on essential physiological foctor.A special unit in which the desired quantity of air can be adjusted is provided for soil aeration.

The temperature control in the soil zone is similar to that of the green zone, corresponding elements being used. What is controlled is the ambient air. *Due* to the air movement, the temperature differences between the air and the boxes or pots are rapidly balanced.

The soil moisture is controlled by a highly sensitive thermal detector opening a magnetic valve, so that water from a tank can be injected into the soil through spraying nozzles.

Fresh air is supplied to both zones, the flow being manually adjusted for each of the zones separately. Flow meters indicate the quantity. Owing to a pressure control ensuring uniform performance of the diaphragm pumps, the flow of fresh air, once adjusted, remains at a constant level. The diaphragm pumps inject fresh air unpolluted by oil, etc... into the test chamber. The dew point control for the two zones is based on the control of temperature at 100per cent saturation with water vapour. With the help of a mechanical control valve and an electrical heater the temperature regulator with the resistance thermometer controls the temperature of the humidifier. Refrigerant pumps feed the jacket of the humidifier with cooling liquid. The latter ensures purification of air the humidity of which is raised to 100 per cent. r. h. For dew points below 0°C an afterdrier is used. In this case the humidifier is maintained at a temperature above 0°C.

The value desired is ajusted by simply *turning* two knobs to the position indicating the desired value, which may be different for day and night. An automatic clack ensuring exact adjustment of switching times effects the change from day to night values and vice versa.

The refrigerator and the tank containing the cooling liquid form a separate unit within the Phytocyclon, which unit is connected with the main body by an insulated pipe. For normal climatic conditions the refrigerating unit has a capacity of approximately 15.000 kcol/h of an evaporation temperature of-10°C.

The Phytocyclon can be adapted to work with artificial light using XENON lamps, which so for most nearly approximate the solar spectrum.

PHYTOCYCLON - TECHNICAL DATA :

Wind velocity	0 - 100 km/Ii.
Temperature of the green zone	- 10°C ..... + 60°C + 0,25°C
Temperature of the soil zone	- 10°C .... 4 40°C + 0,25°C
Relative humidity above -4 10°C	1 0 per cent ... 95p.c +2 p.c.r.h.
Relative humidity below + 10°C	20 per cent ... 95p.c. + 2 p.c.r.h.
Soil moisture	0 - 100 per cent of the capacity of water
Soil aeration	0 - 1 liter/h and liter/volume of the soil
Light	1 00.000 LUX max.

A smaller unit designed for research work by RUTHNER is the socalled PHYTOBOX (fig.2). The phytobox was intented to serve as an individual unit of a set of growth and measuring chambers (microphytotron unit). Due to the fact that data can be obtained most rapidly (production testing by measuring assimilation), the Phytobox offers the possibility of carrying out multifactorial experiments.

In contrast to the Phytocyclon, assimilation$_1$respiration as well as transpiration measurements in the Phytobox are confined to the green zone.

The principle underlying assimilation and respiration measurements remains unchanged, it is equally based on the above differential equation. Assimilation curves ore equally recorded by the gas analyser. To avoid any interference with the CO_2 analysis, this chamber is lined with the same material as the Phytocyclon is, a material neither absorbing nor emitting CO_2.

Transpiration, however, is measured by determining, in a graduated measuring glass, the quanthy o's water transpired by the plants within a certain period during the experiment. The Phvo. ox o• eis pdssioilily of regulating car temperature, air humidity, soil temperature, and the supply with a constant fresh air quantity, the dew point of which is automatically controlled over the entire temperature range of the chamber. Flexible tubes attached to the individual plant containers provide for soil watering from outside of the chamber. Diaphragms ensure a gas tight closure, in order to prevent the air from penetrating the pots and entering into the chamber.

The slight overpressure in the chamber first of all leads to a homogenization of the air in the chamber, and secondly it prevents the entrance of uncontrolled air from outside. Both of these factors are of vital importance for measuring the CO_2 balance.

Air temperature and humidity are controlled by a temperature regulator and a dew point regulator, both of which influence the temperature of the cooling liquid circuits.

By frequently circulating the air of the chamber with the help of a fan it is possible to obtain the desired climate within a short period of time (half an hour). In contrast to the Phytocyclon this fan provides for lower wind velocities only (either constant or adjustable).

The Phytobox has a measuring chamber surrounded by a double mantle of transparent and UV permeable material of 300 I. contents. It is suited for experiments with daylight os well as with artificial light. For artificial illumination four Mercury high pressure lamps are used, which provide for a continuous adjustment of the luminous intersity at the plants' level. These lamps can be switched on individually and moved in a vertical direction. When using artificial light, the measuring chamber is darkened and a fan blows the heat off the lamps.

Regulation covers the following ranges for :

Temperature	- 10°C ... 80°C + 0,25°C	
Humidity	10 per cent ... 95 per cent	2 per cent.r.h.
Air circuit	300 times/hour	

Bath the PHYTOCYCLON and the PHYTOBOX offer a wide range of possibilities for experiments including :

- Studies of photosynthesis
- Analysis of CO_2 and H_2O balances under variable environmental conditions
- Studies of planting methods
- Rapid selection in plant breeding by comparative testing of resistance and production.

The efficiency of the Phytocyclon and the Phytobox can be improved by using an analogous computer.

Fig. 3 shows an assimilation curve for soy beans recorded in the Phytobox by gas analysis. The curve (a straight line) -uninterrupted on the recorder tape- describes a controlled air volume enriched with CO_2. The second curve shows the assimilation activity of soy beans.

Assimilation activity of plants in a dry substrate and, after moisturizing, in a moist substrate, markedly increases and reaches a maximum level, when light exposure sets in. When light exposure is terminated, assimilation activity ceases and plant respiration starts, which respiration is recorded in the curve to the right of the fresh air curve.

What resembles an exponential rise and fall of the assimilation curve is due to the chamber volume, the effects of which cannot be excluded.

Waiting for the balanced phase requires a certain period of time during experiments, the duration of which is determined by the chamber volume and the supply with fresh air.

The part of the above differential equation designated by the term $V. dg/dt$ disappears, when instead of neglecting the chamber volume (V), dg/dt is reduced to O.

Stationary equilibrium is then achieved.

However, it is not necessary to wait for this balanced phase, when $\frac{d\varphi}{dt}$ is multiplied by V and the sum total is drawn.

This is done with the help of a continuously operating analogous computer specially designed for this purpose.(x) A condenser absorbing a current i (t) of the magnitude $C\frac{du}{dt}$ at a voltage of u (t) was used as a differentiator.

In fig. 4 the analogous magnitudes are contrasted. The above differential equation is thus transformed to a differential equation containing electrical terms only : $i = C\,\frac{du}{dt} + \frac{1}{R}\,u$. By superposing an analogous computer this gas analysis method becomes independent from the chamber volume.

The analogous computer enabled us to reduce the time required for individual measurements to 1/8 of the time previously required. This permits of an immediate registration of even the most rapid changes in the assimilation activities of plants.

The recorded curve in fig. 5 was complemented with the values obtained by the analogous computer. It is no longer necessary to wait for the balanced phase to be reached and the recorded value to remain constant ; the analogous computer computes the actual assimilation value for any given moment, which value could not yet be read from the curve.

Fig. 6 and 7 show the results obtained in a climatic chamber by gas analysis and analogous computer. Light and temperature dependence of assimilation was registered for tomatoes (fig. 6) and for green peppers (fig. 7).

The curves' parameter is ambient air temperature, the assimilation value being plotted against the ordinate, the luminous intensity selected against the abszissa.

These curves reveal a difference in light and temperature dependence for various species of plants and different locations on the curve of optimum assimilation values dependent on temperature.

As indicated above, the PHYTOCYCLON'S scope of application will particularly cover special plantphysiological studies as well as ecophysiological experiments designed to determine the plants'resistance to extreme climatic conditions (e.g. plant selection for reafforestation purposes of high Alpine areas, cultivation of arid zones). The PHYTOBOX is designed as a microphytotron unit suited for rapidly determining, by gas analysis, the physiological response and production of the plants growing in the chamber, which ensures a wide range of possible experiments and will supply a large number of valuable data.

The fields of application offered both by the PHYTOCYCLON and the PHYTOBOX can naturally be extended to cover biological studies going far beyond the scope of phytotronics proper. By designing the Phytocyclon and the Phytobox we hope to have further contributed to overcoming another one of the technical obstacles barring the way to constructive research work in an important field of biology.

⁂

(x) H. MILLENDORFER and BORGHORST : Analogonverfahren bei pflanzenphysiologischen $C0_2$-Messungen (Analogous procedure in plant physiological $C0_2$ measurements). Verbatim proceedings of the Austrian Academy of the Arts and Sciences.

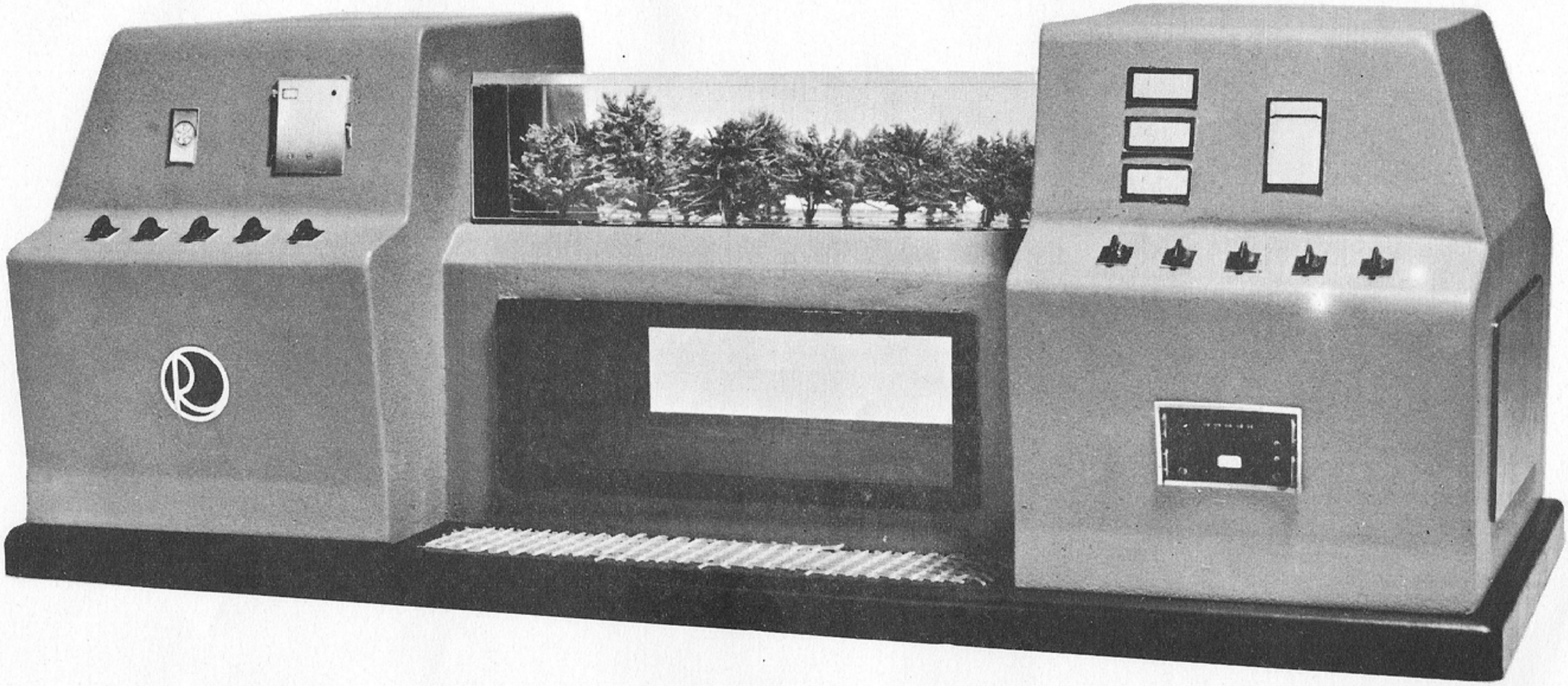


Fig. 1.- Ruthner Phytocyclon.

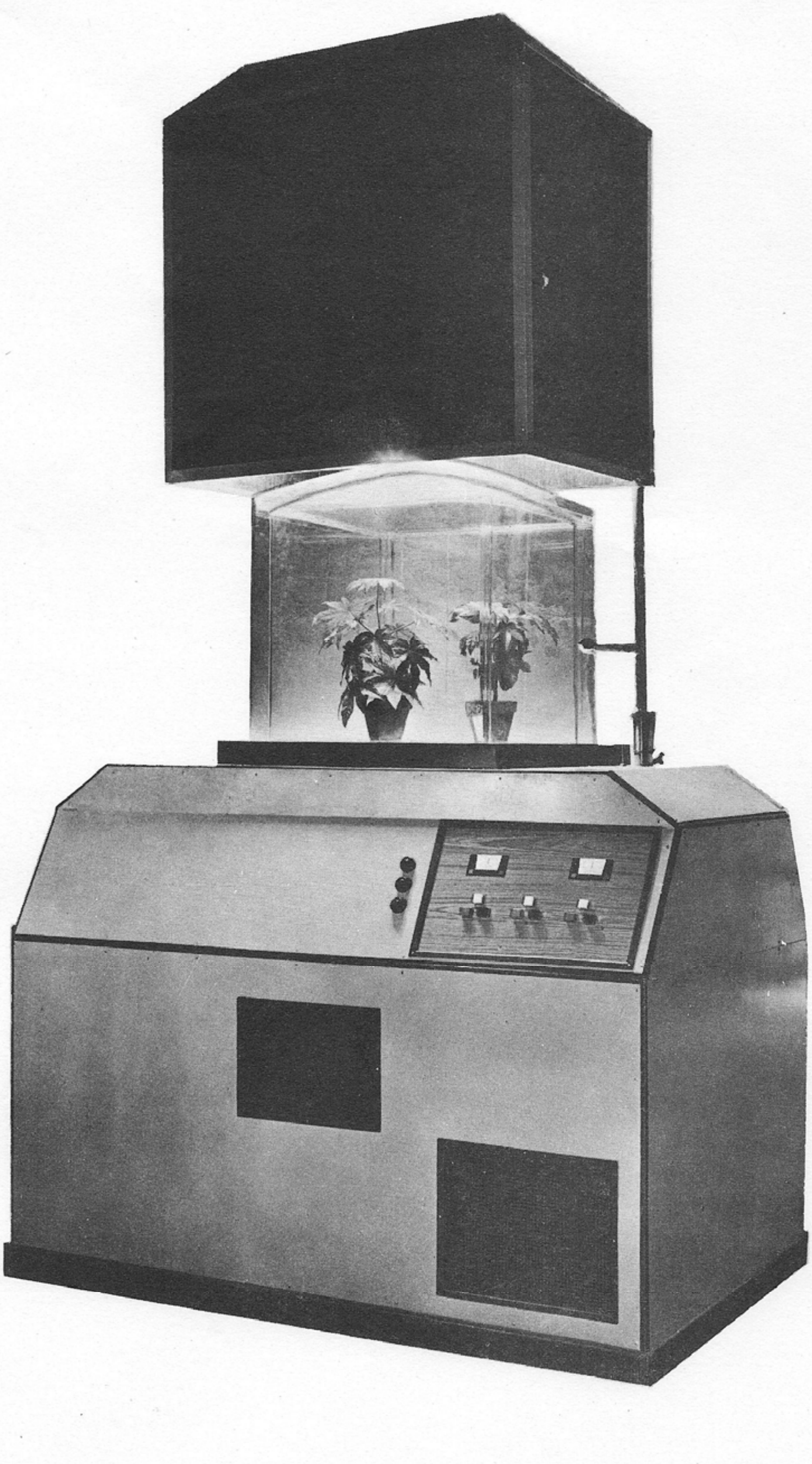


Fig. 2 .- Phytobox.

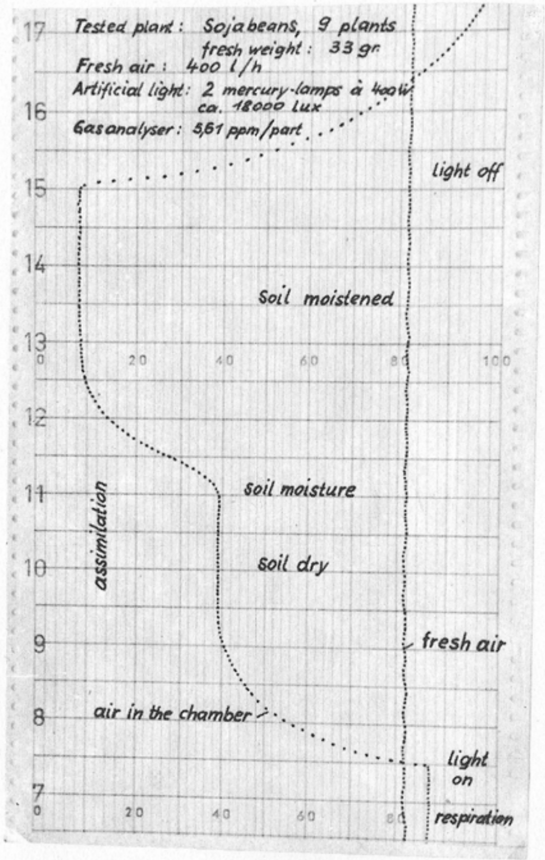
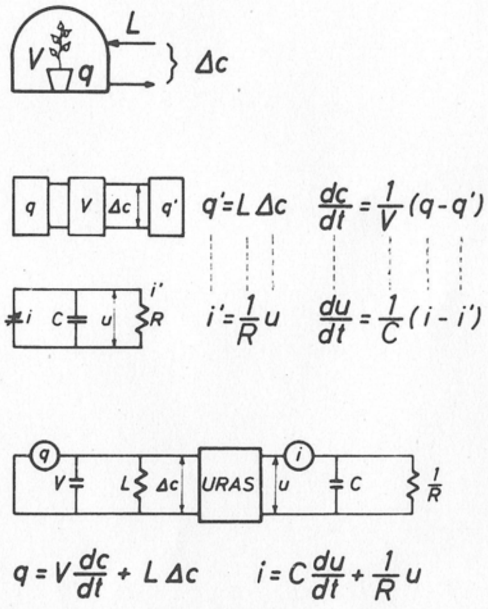


Fig. 3 .- Assimilation curve for scybean recorded in Phytobox by gas analysis.



$q' = L\,\Delta c$ $\quad \dfrac{dc}{dt} = \dfrac{1}{V}(q - q')$

$i' = \dfrac{1}{R}u$ $\quad \dfrac{du}{dt} = \dfrac{1}{C}(i - i')$

$q = V\dfrac{dc}{dt} + L\,\Delta c$ $\qquad i = C\dfrac{du}{dt} + \dfrac{1}{R}u$

Fig. 4 .- Gas analysis method.

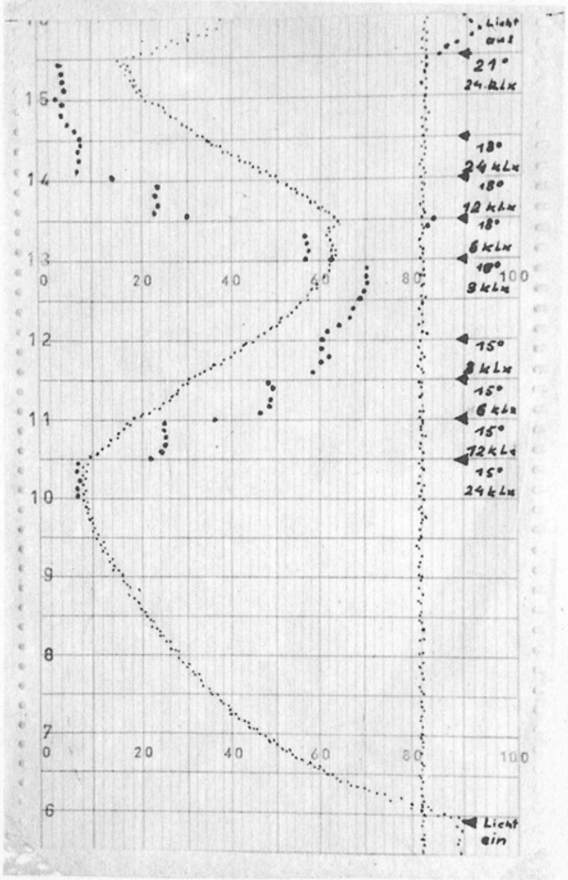


Fig. 5 .- Curve of assimilation activities of plants.

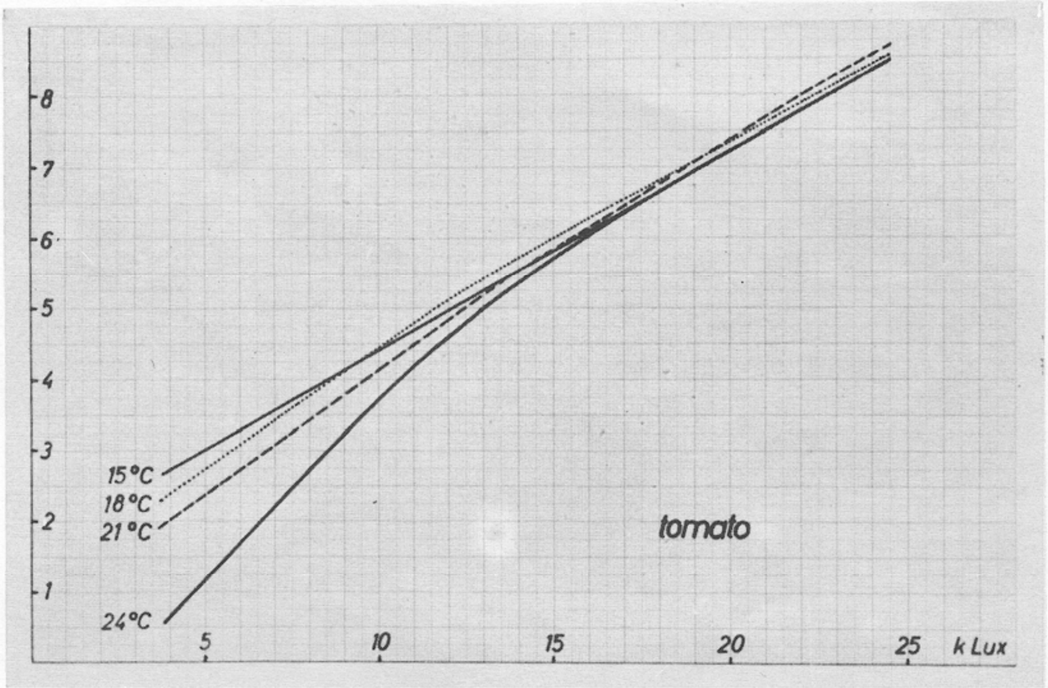


Fig. 6 .- Assimilation curves of tomatoes.

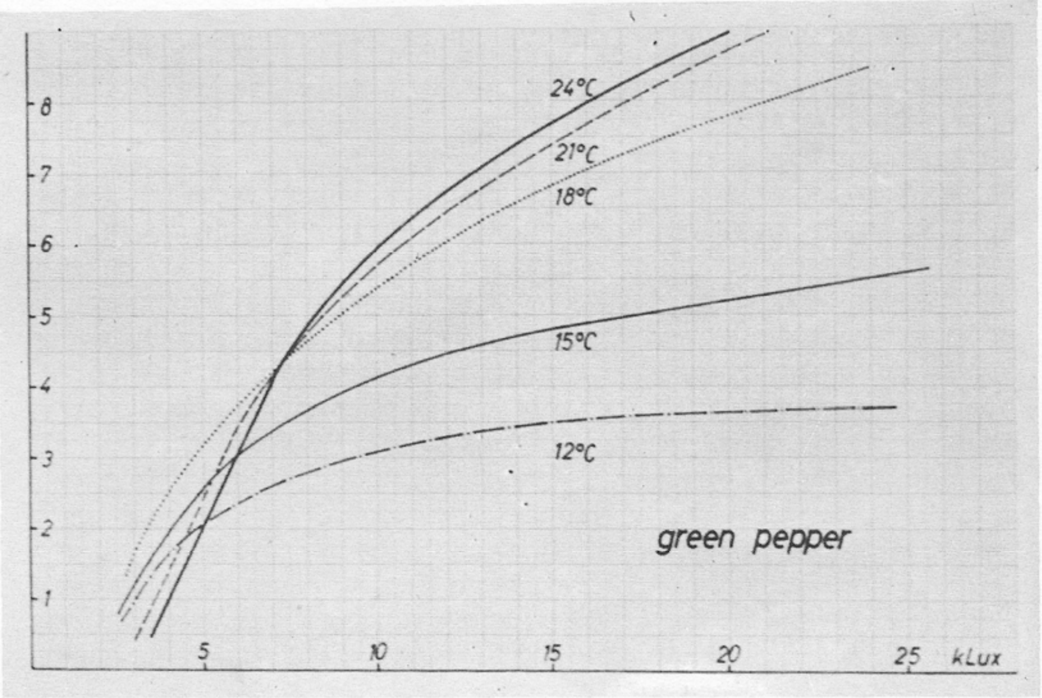


Fig. 7 .- Assimilation curves of green pepper.

A CRITICAL COMPARISON OF VARIOUS TYPES OF PHYTOTRONS

by

J.P. NITSCH[x], Associate Director of the Phytotron, Gif-sur-Yvette, France.

There are exactly 15 years since the first true phytotron was dedicated at Pasadena, in June 1949 (and since _lames Bonner, making a pun on the word "phytotron"coined the word "phytotronics"). It just occured to me that among all this distinguished audience, I am the only one who attended this ceremony. This I say with a note of sadness, because the father of phytotrons, Prof. F.W. Went, is not present with us here. He would be much more qualified than me to speak about the subject Since it so happens that I was the first of this group to work in the Pasadena phytotron, it is perhaps fitting that I give a sort of review about how the field has developed since that time. This I will do by avoiding to show another deluge of pictures, but by trying, on the contrary, to think about what is important in a phytotron.

What is important in a phytotron ?-You will grant me, I think, that it is not the building, however impressive and beautiful. Nor should one brag about how costly his phytotron is (as a matter of fact the aim is to reduce the cost as much as possible). But it is the degree of control over the various environmental factors which is the important thing in a phytotron. Let us review, therefore, which factors should be controlled and, then, compare the performances of various types of phytotrons.

WHAT FACTORS SHOULD BE CONTROLLED ?

I.- Nutrition .- The first factor which should, and can, be controlled is nutrition. After all, plant physiology has now advanced to a stage where it is possible to compose a synthetic medium on which one can grow any type of plant.

This we have done at Gif, For example. A standard mineral solution is produced in one part of the building, stored in a plastic tank of 2,000 gallons in capacity and then distributed in plastic pipes throughout the whole phytotron, in the same manner as it is clone at Pasadena. At the present time, we use about 500 gallons of this solution per day, but the consumption will rise when all the facilities will be in use.

Water is a problem with us. We pass it first through a sand filter, then deionize it over resins. However the modern housewives use detergents to wash clothes, and these detergents Flow into rivers. The normal drinking water at Gil comes from the Seine river and, although it has been filtered, disinfected and is perfectly safe to drink, it contains detergents which go through every Filter and every deionizing column. We ore presently trying to tap a spring near the Phytotron in order to provide detergent-free water for at least the nutrient solution.

Another question to be solved was the material for supporting the roots. I have tried different types, including glass beads, which, when of the right size, work reasonably well. The aim was to obtain a medium which could be reproduced exactly year after year. Gravel can be variable, depending on what part of the quarry it comes from. Besides we do not have, near Paris, quarries of stones without lime, and Fontainebleau sand (which is pure quartz) was found to pack badly. Thus after various experiments, we are now using a special type of glass

---

[x] actually : Director of Laboratory of Pluricellular Physiology, Gif-sur-Yvette, France.

fiber called "Verrone" which gives fairly good results. It also eliminates the necessity of sterilizing it, as it does not contain the insects and pathogens which may occur in gravel. Finally, it has the advantage of forming on intricate matrix which holds roots in place when plants are moved on trucks. In order to eliminate the development of algae

in the mass of the glass wool, we cover it with on inch of Vermiculite which prevents light from penetrating into the rooting medium.

We can also control the quantity of nutrient solution given to any pot by a device which operates an automatic watering system. To each pot goes a thin, black (to prevent algal growth), plastic tube, through which the solution drips at pre-determined times, and for the length of time desired. This system has been functioning satisfactorily in our "Supergreenhouses", about which I will speak later. It is not easily adopted to plants which have to be moved in and out of rooms every day, as is done in phytotrons patterned after the Pasadena system.

With these installations it is possible to control remarkably well the nutritional factor as far as quantity, quality and periodicity are concerned.

2.- Composition of the air .-A second point which should be controlled in a phytotron includes at least two aspects of the composition of the air, namely (a) the removal of various particles or gases , (b) the CO_2 content.

The removal of dust particles, pollen grains, spores, insects, etc..., is done at Pasadena by passing the air through electric precipitators. At Gif, we filter the air mechanically through large "Poelmon" paper filters. Just as an indication, we use something like 334,000 cubic meters of air per hour. About 100,000 cubic meters of fresh air are taken from outside every hour. Some 140,000 cubic meters/hour are used to cool the lamps and ballasts for the rooms receiving artificial light. The air should also be free from ozone (which can be generated by xenon arc lamps) and of smog (the example of the Pasadena phytotron has shown how important this later factor may be). Activated charcoal filters off smog very effectively.

The CO_2 level, of course, is important. However, I am not going to expand on this point, since our colleagues from the German phytotron at Rouisch-Holzhausen will present a paper on this subject.

3.- Temperature .- Temperature is the factor which has been most carefully controlled in all phytotron. It is generally maintained of the desired level by adjusting the temperature of the air, so that, in this, the rate of air movement becomes very important. From some of the results we have obtained at Gif, f conclude that an air speed of half a meter per second is not sufficient to remove calories fast enough under lighting in order to prevent the formation of a distinct temperature gradient from floor to ceiling.

It is also important for one to be able to maintain the roots at a temperature different from that of the stem and leaves. This is generally done by inserting the pots in a bath in which circulates water at the desired temperature.

4.- Light.- Light, of course, is a most important factor of plant life and should be carefully controlled as far as quality, intensity, and periodicity are concerned.

a) Light itEmliti : Quality of light is a major item since white light is a mixture of radiations and since it is known that, if one separates the various wavelengths, one gets very different results depending on the wavelength used. One of the aims of artificial lighting has been to reproduce a spectrum which was more or less similar to that of sunlight. To this effect a mixture of fluorescent tubes and of incandescent bulbs has been used in many instances. At Gif, for example, we have 2,688 fluorescent tubes (Philips "double flux" type, 125 **watts)** interspersed with 7,560 smolt, 15 watt incandescent bulbs. The latter contribute the radiations above 700 1-rpt in which the fluorescent light is deficient. I should say that we have not determined what is the optimal ratio of incandescent to fluorescent lamps.

Phytotrons should also be equipped with devices providing monochromatic light. Here the difficulty is to provide both purity of the spectral region desired and intensity over a surface large enough to treat relatively large plants'. A spectrograph of relatively high energy is under construction at Gil.

b) Intensity : The banksof lights which cover the entire ceiling of the artificially illuminated rooms give us between 2,000 and 3,000 ft/c., that is a light energy of 3 to 4,5 watts per square foot at the plant level. This is sufficient to provide excellent growth for most species. For example we have raised from seed vigorous sunflowers which, although they never saw sunlight, produced enormous flowers. On difficulty with flat ceilings is to obtain a uniform intensity in all parts of the room. Some phytotrons compensate for the decreasing intensity on the sides by installing extra lamps at the upper part of the vertical walls; this is the case in the Japanese phytotron at Fukuoka. Of course, a high wall reflectivity will improve matters. Aluminium foil is used at Reading for this purpose. At Gif we have white point. Another problem springs from the fact the light output of fluorescent tubes decreases with age. After the first thousand hours or so, the intensity given by the Philips 125 watt tubes has decreased to about 1/3 of its initial value. This is a major headache for us, and we are aiming at a mixture of used and new tubes which will give a constant light intensity throughout the year.

c) Periodicity : Another important feature of light, as far as plant growth is concerned, is its periodicity. In phytotron which have large rooms like that at Pasadena, plants are placed on trucks which are moved from one room to another at the proper time. If one uses only artificial light, one can just have is turned off by means of automatic clocks. In the case of natural light, one needs some type of shutters, such as the ones used at Canberra to darken small cabinets automatically. At Gif, we have devised a system of a much larger size which darkens whole greenhouse compartments measuring 10,75 x 3,60 meters, with a height of 3,50 m at the center. This is done by means of a metallic curtain which is rolled around a drum (outside the greenhouse) during the day and which, at the proper time, is pulled to cover the top of the compartment. The sides are made light-tight by vertical sheets of metal composed of several horizontal segments which, during the day, are housed side by side between the floor and a height of about 1 m. A similar system functions in the glass door.

Finally I should mention that we have installed a special switchboard in the Gif phytotron in order to produce sunrise and sunset-like effects by turning the artificial light on and off gradually. It is not known yet if variations in light intensity of this kind have an appreciable effect upon plant growth.

5.- Humidity .- The perfect control of humidity is difficult technically and, consequently, very costly, at least in a large room. One wonders if it is worthwhile to spend large sums of money when one knows that the humidity of the air has only a slight influence on plant growth as long as they watered properly. The fact that one can grow beautiful tomatoes, lettuce and even strawberries in the Sahara Desert exemplifies this point. However the development of pathogens, both fungi and insects, is very dependent upon air humidity. If one wants to study pathogens, he will have to control this factor in some manner ; but if one excludes pathogens from his phytotron, the maintenance of on average value of 50-70 % relative humidity, as done at Pasadena, fills most purposes.

6.- Rain .- A factor which is linked with huknidity is rain, which can be simulated relatively easily with various types of overhead sprinklers. A point to watch is the composition of the water.

7.- Wind The study of wind may be of great practical importance, and so it is pursued at places like Fukuoka (Japan). Funnels producing winds of measured velocities and of variable orientations are used to study the effects of typhoons.

8.- Gravity .6ravity is an important factor in plant growth and development. So for, it has been studied mostly with the help of klinostats in which the centrifugal force interferes with that of gravity. The best place to investigate the effects of the absence of gravity will be, of course, the space ships.

9.- Freedom from diseases .- If one wants to study the effects which environment has upon plant development as such, one wants to eliminate the interference of parasites of all kinds. This was well emphasized by Went who established in the Pasadena phytotron a strict policy of disinfecting the building, the artificial soil, and all instruments, and of making people who enter the phytotron change their outer clothing. Of course another method is to hove a regular spray program, but red spiders become resistant to sprays, and residues may interfere with some types of experiments. Thus, policies which prevent infestations are always favored over those which try to combat them, once they have started.

TYPES OF PHYTOTRONS

After the enumeration of the various factors which should or could be controlled and which will be taken up again in our discussions during these two days, may I now turn to the various answers which have been given to the different problems. To me, there has been three fundamental types of phytotrons so for, although this, of course, is simplifying things very much. These types are : (1) the large room type, of which the Pasadena phytotron is the first example ; (2) the small cabinet type which has been developed in such an outstanding way at Canberra, and (3) the supergreenhouse type such as the one which has been functioning at Gif for about three years now.

I think I can give a sort of appraisal of these three types because it turns out that we have all of them together at Gif. Comparisons made between the Gif examples may be more valid than those which could be attempted *between* Pasadena and Canberra, for example, as certain factors such as cost of labor, materials or power may *be* very different in different countries. Therefore I hope you will excuse me if I base my discussion upon what we have at Gif.

I.- The large room

Principle : The first type of phytotron, realized initially at Pasadena, consists of a series of rooms which are all similar except for one variable at a time, namely generally temperature or light. Each room has its own machinery which provides constant conditions in general. Variations are provided by moving the plants from one environment to the other. Thus with a relatively limited number of rooms, one can obtain a large number of possible combinations.

Technical features : Temperature is kept at the desired value by conditioning the air and changing it rapidly (about two volumes per min.). The mass of air enters the room through the whole floor surface at both Pasadena and Gif, then rises vertically, to leave the room through openings placed as high as possible on the side wails. This air is reconditioned in temperature and humidity, a certain percentage of new air added to it, and the cycle recommences.

In the case of rooms lighted with artificial light, we have made measurements of the air temperatures or various levels, using a Model 60 Anemotherm Air rWter (manufactured by the Anemostat Corporation of America, Scranton, Pennsylvania). Lets take the example of one of our rooms which is mainbined at a constant temperature of 17°C. At 10 cm above the floor, the temperature was 14°, at 60 cm it was 15° and in the zone comprised between 1.1 m and 1.5 m, it was 17°. This is, of course, the zone in which we have the plants, our trucks being 1 m high. But as plants become taller, they grow out of this zone. About 10 cm below the sheet of glass which separates the bank of lights from the growth room, the temperature reached 21°C. If we lower the plant, as can be done with trucks which have adjustable platforms, we place the roots in a zone chich is cooler than 17°. In short, if plants are less than 40 cm tall, they can be grown at the specified temperature ; but, if they are taller, some ports of the plants are not at the required temperature. The presence of such a gradient in temperature between florr and ceiling is due to a relatively law air velocity 0.5 - 0.3 m/sec. I think that we could decrease the temperature gradient if we could increase the air velocity.

The banks of lights are conditionned independently with dry air, which keeps the fluorescent tubes operating in the temperature range where light output is at a maximum.

Advantages : Phytotrons with large rooms in which plants are moved according to the conditions required offer the possibility of many different, simultaneous combinations. This seems to be their main advantage.

Disadvantages : In addition to the presence of temperature gradients (which is rather serious in the case of large plants), there is the danger of fight leaks because, both at Pasadena and at Gif each room with artifiol light has been divided into compartments with different light regimes. Partitions between these compartments are opened every day and, if the gardeners do not always close them carefully, light leaks may ruin some photoperiodic experiments.

The problem of moving the plants twice a day is also a real one. Firstly it requires a large manpower every day, on holidays as well as on work days. Secondly, in practice, there are lots of plants to move at the same time, so that gardeners have to go fast, pushing strings of trucks together. In this process, roots are shaken up, and the leaves of large plants are bruised. Then, of course, these movements are subject to human error ; somebody can make a mistake and wheel a truck into the wrong room. Unless you ore told about it, you may never know what has happened to your experiment.

Finally, I feel that there is a lack of flexibility in the large room system. Because of their size, these rooms are naturally used for more than one experiment at a time and by more than one worker. This means that they have to be set at an arbitrary temperature : this room at 12°C, for example, the next one at 15°, if someone wants 13°, well one can't give it to him, and he has to be content with the nearest available temperature.

2.- The cabinet type .-

Principle : Phytotrons of the cabinet type operate with a large number of small, independent units. The best example of o large phytotron built on th is principle is the CERES of Canberra. In this phytotron a lot effort has been devoted topracticaland economical considerations such as the storage of solar heat in the form of calories transferred to a pool of water, etc...

Technical features : At Canberra the cabinets are placed in greenhouses in which the temperature is maintained above the highest temperature desired in anyone of the cabinets. The cabinets themselves ore equipped only with refrigeration which brings their temperature down to the desired level. They are also equipped with automatic shutters and a few light bulbs for daylength control. Because theydo not possess any heating elements, the Canberra cabinets are not fully independent.

At Gif, on the other hand, I hod made a series of completely independent cabinets which I call "microphytotrons". They are completely autonomous in that they can heat, cool and humidify the air, water the plants with nutrient solution, turn on and off the lights as well as automatic shutters. All they need is to be plugged into an electrical outlet. Measurements made inside have revealed that the temperature gradient is suprisingly in the order of + 0,5°C from the set temperature. This is probably because of a high air velocity (between 0,5 to 1,5 m/sec.) and perhaps also because the air sweeps the plants horizontally, which is a more natural way than ascending vertically from below. With the lighted panels we have, the light intensity is good, from 1,500 to 3,700 fic that is a light energy of 2,25 to 5,55 watts per square *Foot*. The automatic watering system is a wonderful feature. The reservoir has to be filled every three days, which means that these units can work over the week-ends without any gardener.

Advantages : The advantages of small cabinets are numerous :

a) reduction of the temperature gradient, as is the case with our microphytotrons ;

b) complete automation (no personnel necessary on holidays, at least for the microphytotron type) ;

c) greater flexibility : research workers can set the temperature cycles they want ; when they are through with the experiment, other research workers can take over ;

d) case of maintenance : when one unit breaks down, one puts the plants in another unit, while the first one is being repaired ; in phytotrons of the large room type one may hove to close down a whole room or even the whole phytotron, thus interrupting many research projects ;

e) possibility of having a stand-by, electrical generator in case of power failure ; the CNRS has never agreed to give us one for the whole Gif phytotron, because it would be too costly ;

f) possibility of controlling the composition of the air ; in large rooms in which people go in and out and from which plants are wheeled in and out twice every day, an accurate control of the composition of the atmosphere is not possible ;

g) reduction in the number of personnel, especially on holidays which are always a headache in phytotrons of the large room type ;

h) reduction in the running costs (electricity, etc...) : large room type phytotrons have to be kept running whether there are 500 plants in a room or 5 ; small cabinets con be turned off when not in use.

Disadvantages :It is mainly one of size. The cabinets are usually small, perhaps 3-4 feet in height, 3-4 feet in width *and* 6 feet in length. If one wants to study trees, or maize, or surgorcane, past the seedling stage, they cannot be used. However taller units have been built for these purposes at various places, for example at Canberra, at the Sugar Research Institute at Honolulu or even, in the form of non-mobile "phytotronettes" at Kyoto University.

3.- The Supergreenhouse type .-

The third type is what I call "Supergreenhouse" because it is just that a greenhouse which is much more than an ordinary one, in that it has temperature control, doylength control and automatic feeding.

In the supergreenhouses which we have constructed at Gif, the air is injected vertically along, the lateral partitions of each of the 10,75 m x 3,60,compartments. The air rises to the ceiling and then comes down, mixing very well until it reaches the evacuation openings which are located on the floor, under the benches . This disposition has given us a good distribution of the temperature, with less than a 2°C gradient around the plants in mid-summer, when the sky is overcast. When the sun is shining, differences may be greater. The air velocity around the plants varies from 0,3 to 0,7 rnfsec.

In regions of the world where natural humidity is low, the air may be cooled very cheaply by the evaporative cooling obtained with the moist pad and fan technique which is much in use in the United States.

At Gif we are experimenting with heat-absorbing glass. A brand call "Ombral" which absorbs most of the infra-red radiations is used for the top of the greenhouse, the sides being equipped with normal gloss. The Ombral glass gets warm, of course, **and** should be cooled with a flow of water. When this was done in experimental 1 x 1 m boxes, a reduction of 10°C in the inside temperature was recorded os compared with the temperature obtained inside a similar box, covered with normal, uncooled glass. The Ombral glass also cuts down some of the red radiation, however, so that it is perhaps not the perfect material yet for glasshouses.

Our supergreenhouses are equipped with the large, external, automatic shutters which I hove mentioned at the beginning,with the automatic system which delivers to each pot the measured amount of nutrient solution, as well as with benches for mist propagation.

Advantages :- They include : law cost of operation ; the fact that large plants can be grown, as there is space (as compared with the cabinets) and no nOving of plants (as in the large-roorrrphytotron type) ; the possibility of installing an automatic distribution of nutrient solution ; the easy cleaning of the floors, since the air is not insufflated through them.

Disadvantages .- The precision of temperature control is fess than in true phytotrons, especially if one does not use a machinery as expensive as that of a phytotron. Lighting, of course, is that provided by the sun under local climatic conditions, but supplementary lamps can be added, as has been done at Gif to lengthen the days in winter.

- L'expose oral s'est prolonge par une discussion relative aux prix de creation et de fonctionnement de diverses sortes de phytotrons dont les donnees numeriques sont minter-Kul perimees et ne correspondent plus a la realise actuelle.

CONCLUSIONS

In conclusion may I say that a well-balanced phytotron should really have as least two of the three types I have mentioned. It needs supergreenhouses for two main purposes, manely (o) to house the preliminary experiments, and (b) to raise plants up to the size and the physiological state at which they will be used for experiments in the phytotron. it needs cabinets in order to do the critical experiments or large, fully-conditioned rooms, the former being more flexible in accomodoting workers who need odd temperatures or periodicities. Phytotrans which large rooms are hard to manage For two reasons :t:r) the constant movement of plants and (b) the fact that running costs are the same, whether there are many or just a few plants in the rooms. For good management these rooms should always be Filled to capacity with very worthwhile experiments. After my experience with the Gif phytotron, if I had to build o new phytotron, I would have supergreenhouse and cabinets. This is precisely the solution which has been adopted at Canberra. With such a combination, *one* can do practically all the usual experiments economically.

DISCUSSION

Frankel .-I think you will agree this review was well worth the time that it took, and we are very grateful to Doctor litsch for having made it. He has given us in a very useful way the three main types of phytotrons and, I think, to many of us the supergreenhause, which few of us have seen, was the real novelty in this speech.

THE PHYTOTRON IN RAUISCH-HOLZHAUSEN.-TECHNICAL DETAILS AND EXPERIENCES

by

Dr. B. BRETSCHNEIDER-HERRMANN
from the institute of Plant-Breeding and Plant-Cultivation of the Justus Liebig-University of
Giessen - Director : Prof. Dr E.V. BOGUSLAWSKI.

The phytotron of the Institute of Plant-breeding and Plant-cultivation of the University of Giessen has been ser running in 1961. Since several experiments have been carried out and they brought valuable experiences not only with regard to reactions of plants on climate conditions but also to technical functions of the machinery and to the usefulness of the construction in general. So it seems worthful to give a short description of the phytotron and to note some special technical problems.

The phytotron h-as eight climate-rooms and two cold-rooms . The climate-rooms are to regulate in practical use in temperature from + 4 to + 40°C, in the relative humidity of the air from 55 to 96 %, in a certain way in artificial light up to 35.000 Lx and in four chambers wind up to 4,0 rri/sec. can be made. In four chambers finally the CO -concentration of the air can be controlled and regulated from normal up to 3,00 Vol. %- The two cold-rooms have a cooling-system only and temperatures of -20°C can be reached and kept constant. It is not possible to cultivate plants in the cold-rooms for longer periods because there is given no possibility for sufficient light-intensities.

A ground floor plan is given in Fig. 1. In the center of the phytotron two rows of each four chambers side by side are constructed. They oll have a joint corridor from which the rooms are to enter. The one end of the corridor is enlarged to the control-room, which takes up the switch-boxes with panels to control the whole air-conditioning system (Fig. 2). Beside this room are the two cold-rooms, which are to enter from the preparation-and harvest-area. Each behind the two rows of chambers is a corridor, which takes up the technical equipment for air-conditioning (Fig. 3). These two corridors on their ends have a connection, from which one door leads outside and another is to enter the boiler-room. The laboratories in the upper Floor and the outside potstation as well as the sand- and soil- bins are to enter from the preparation-area.

This construction in the first four years of practical work has proved as a good one in general. Especially the place of the switch-boards and control-panels seems to be the best for there is no difficulty to reach the chambers or the machinery in the outer corridors on a short way. This often is necessary when control-works are going on or breakdowns are to repair. On the other hand machinery itself takes no place there where it is necessary to serve the plant-pots. But it is to remark that corridors and rooms for machinery should not be too tight in construction, because there should be spaces for improvements. Technical developement goes foreword and should be realized in the phytotron to keep it up-to-date. In this phytotron here is scarcely any place in the control-room or in the central corridor to install e.g. on additional recorder. Dressmaking of the walls around the technics was nearly too perfekt to spare money.

The construction of a chamber and the principle of air-conditioning is shown in Fig. 4. Each room is 3,00 m. long, 2,25 m wide and 2,40 m high. The air enters the room from the Floor made by perforated stainless steel. The tops of the wheeled tables, which are to vary in height, are made of wire-gauze and allow the air to pass pots and plants vertically. The air leaves the chamber for reconditioning by two return-air-ducts fixed in the long corners of the room. The air-ducts join on the backside of the chamber and here a fan presses the air into the air-conditioner, where it is cooled and dried. Now the air passes the steam-heater and the electric-heater. The latter only comes automatically in action if there is a break-down of steam supply. At last steam regulated by solenoid valves is given to the air to reach the wonted humidity. Now the air enters a room under the perforated steel-floor, where it is set into rotation and equally distributed before entering the climate-room again.

The insolation of the chambers is from special cork, fastened with bitumen. An aluminium-foil is useful as vapour-barrier. Finally the walls are formed by a concrete layer on which whitecoloured plates of "Eternit" are fixed.

The velocity of the air in the chambers is 0,1 - 0,2 %/sec. That means a change and reconditioning of the air three times in one minute. The loss of air by circulation is about 5 %, which is compensated from outside air in a special duct. A damper makes it possible to mix Fresh air into the circulating from 5-100%as wanted.

Higher air velocities can be produced in four chambers by a fan fixed inside the chambers on the wall (secondary air circulation). The fans, two in each chamber, may be changed in its position depending on height of plant-growth. Each chamber is equipped with two wheeled tables with a surface of 0,65 x 1,70 m. each. They can take up 24 "Mitscherlichpots", size 1, or adequate numbers of pots with another size. As said before the table-tops can be varied in height that growing plants always are kept in the same distance from the light sources (s. Fig. 5).

The lamps , fixed in reflectors as shown in fig. 6, are installed on little cars, which can be drawn out of the lamp rooms for cleaning or repair. A lid prevents light from shining into the central corridor or from here into other chambers. The lamp room is separated from the climate chambers by "Thermopane" - glass (that are two panes of 5 mm glass with dried air between) to prevent heat from the chambers. A fan switched by thermostates is cooling the lamps by taking warm air from the outer corridors (s. Fig. 4) over the lamps to outside. The distribution of light on the tables in I m distance from the light sources is not fully equal. For this reason the pots daily have to be changed in their position, which has a throughoutly satisfying effect.

The type of lamps used are Mercury high pressure lamps with fluorescent ("Philips HPL). From these 6 lamps of 400 W and 2 of 250 W ore installed. They give an overage intensity of 20.000 Lx on the table in 1 m distance, when lamps are new ones.

As the therrnopanes have nearly the some surface as the tables light intensity decreases to the table edges and it would be better to have a lighting area of the whole ceiling of the chamber. But this would mean more lamps, stronger compressors for cooling and last not least for more expensive experiments, so that changing the place of pots daily seems to be a more economic way.

Experiments showed that 20.000 Lx for cereals seems to be a limit to get yields of yellow ripe plants, which can be compared in their height with yields of the pot-station outside. Development and growth of the plants are 'normal". To have a possibility for experiments with other and higher light intensities two technical possibilities were realized :

1.- Use of stronger lamps (700 W instead of 400 W and 400 W instead of 250 W). The result was at first 36.000 Lx in average on the table-top in I m distance from the lamps. Now the yield of oats was higher as ever found under outside conditions. But it is not possible to install these stronger lamps in all chambers for technical reasons (heat radiation bec',mes so high that machinery does not cool the air down to lowest warranted temperatures when light is on and other technical difficulties).

2.- The 400 W and 250 W lamps were used with 500 and 300 W ballasts. In this case with a new set of lamps an intensity of 26.000 Lx was found on the table top (1 m distance). The problem is complicated by the decrease of light-intensity with the number of working hours of the lamps as it is shown in fig. 7. The values were found when in the beginning of an experiment with oats new sets of lamps in all 8 chambers were used. Light intensity decreased after about 800 hours for about 20 % and more. That lamps, which had given in the begining 26.000 Lx at this time gave 20.000 Lx and this we had found to be a limit For "sufficient" yields.

The regulation of CO_2 -over a range from 0,03 - 3.00 Vol. % is made by way of measuring the concentration of CO_2 in the air with two "Uras" (Ultra-red-Absorption measuring) (Fig. 8). The "Uras" gives reliable values of high exactness to a moving-coil system. From here a solenoid-valve is opened when the found concentration of CO_2 is lower than the theoretic value and CO_2 is given to the air on the some way like water vapor for humidity.

At the some time the values found by the "Urns" are written down by a multicolour recorder for controlling. If the desired values are not reached the time of opening the solenoid-valves can be extended. The measuring error of the "Uras" is 1/10 of the measuring range. The regulation error is Fivefold the measuring error.

The temperature is measured by platinum resistance thermomoters and the air humidity by hair hygrometers both fixed on the tables between the plants. They ore teletransmitters and give their measuring-results to controllers in the control room. The exactness of temperature regulation is + 0,5°C, of relative humidity + 5,0 %. The diagram of fig. 9 gives a good impression of the exactness of the temperature and humidity regulation.

There are no program controllers with corns, but two values br temperature and two for humidity can be chosen and become effective by way of time switch-clock one after another. Thus a climate with one temperature and humidity for the day and one for the night can be regulated automatically. Light is switched on and off by switch-clocks too.

The phytotron is kept running by oil cod electric energie. If there is a breakdown of oil or electric supply, it is possible in the first case to work on only with electric energie, because there are additional electric heaters and an electric boiler produces steam for humidity. On the other hand a emergency engine with generator can produce electricity to make the phytotron independent from the electric network-supply.

A complicated alarm-system gives optical and acoustic signals if any technical trouble is going on.

⁂

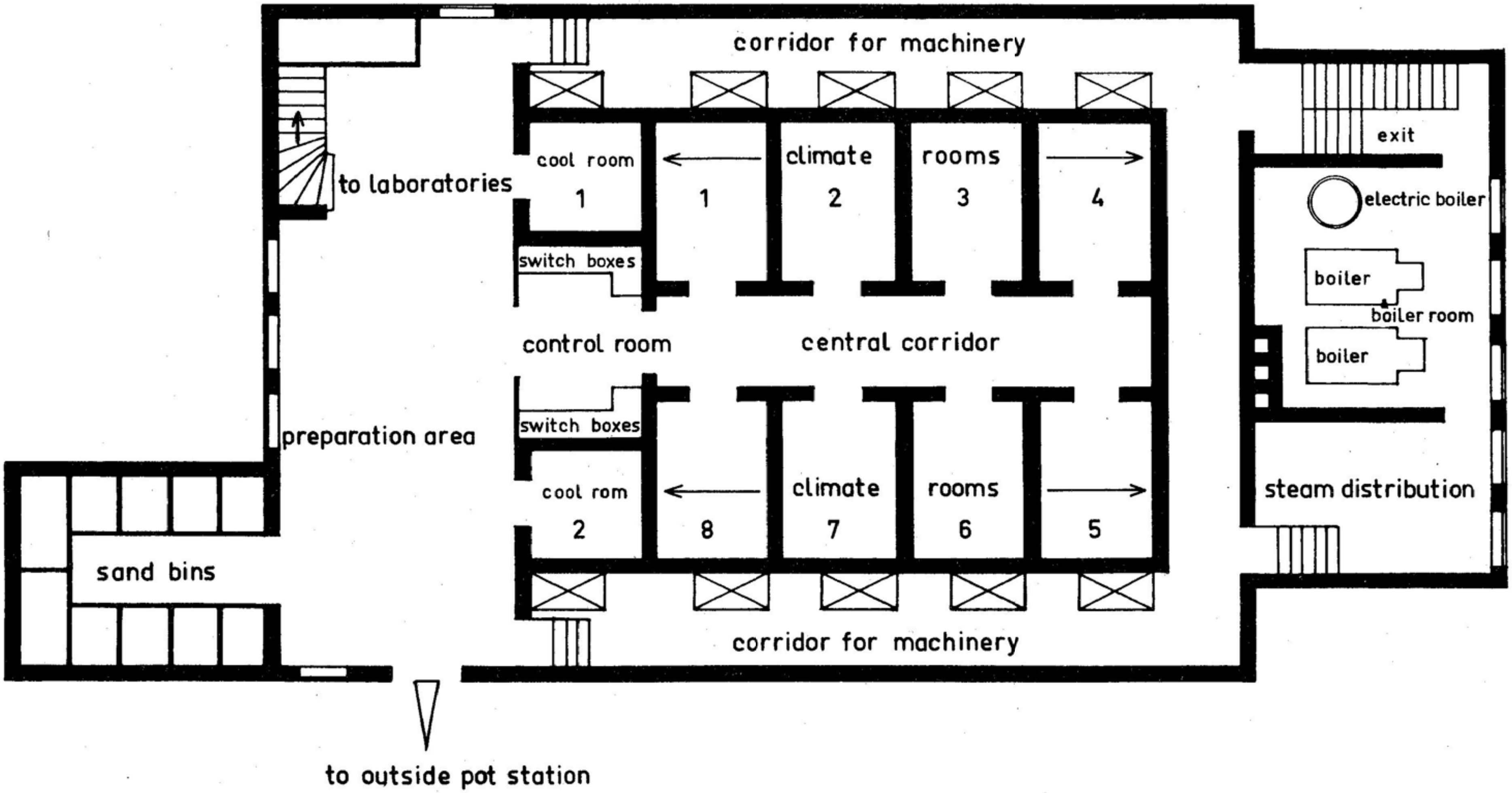


Fig. 1 .- Ground floor plan of the Phytotron Rauich-Holzhausen.

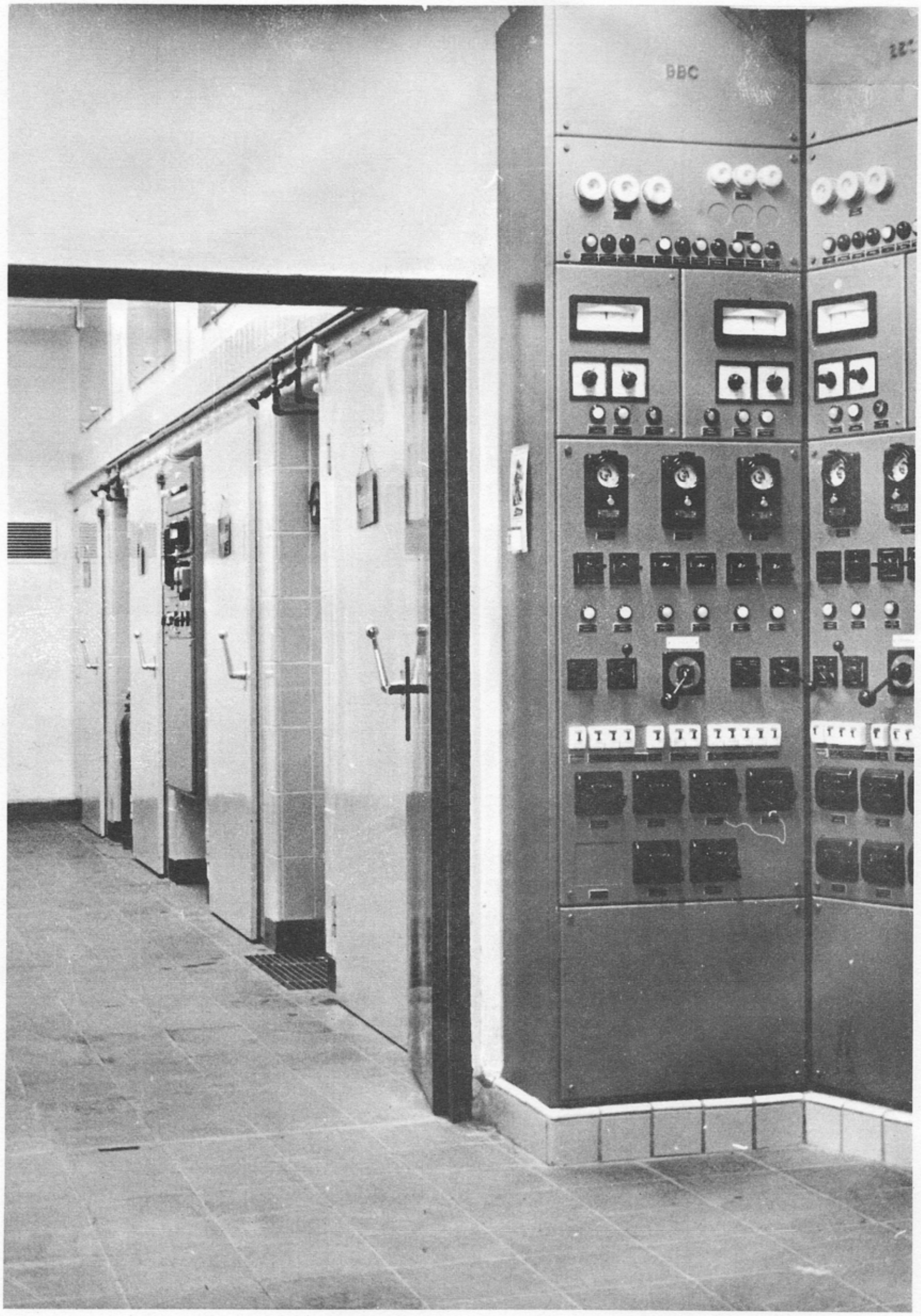


Fig. 2 .- View from the control-room to center corridor.

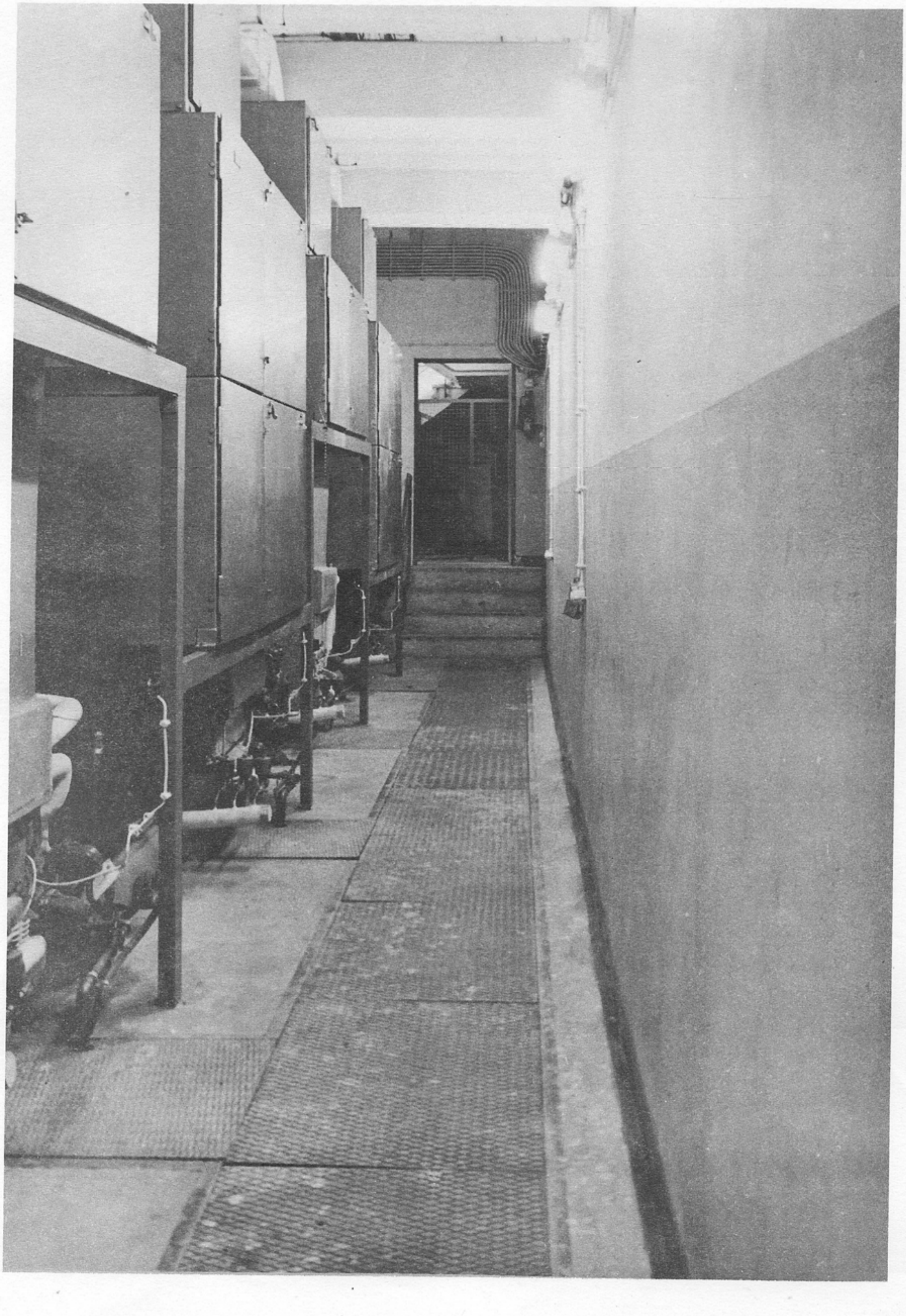


Fig. 3 .- Corridor for air-conditioning machinery.

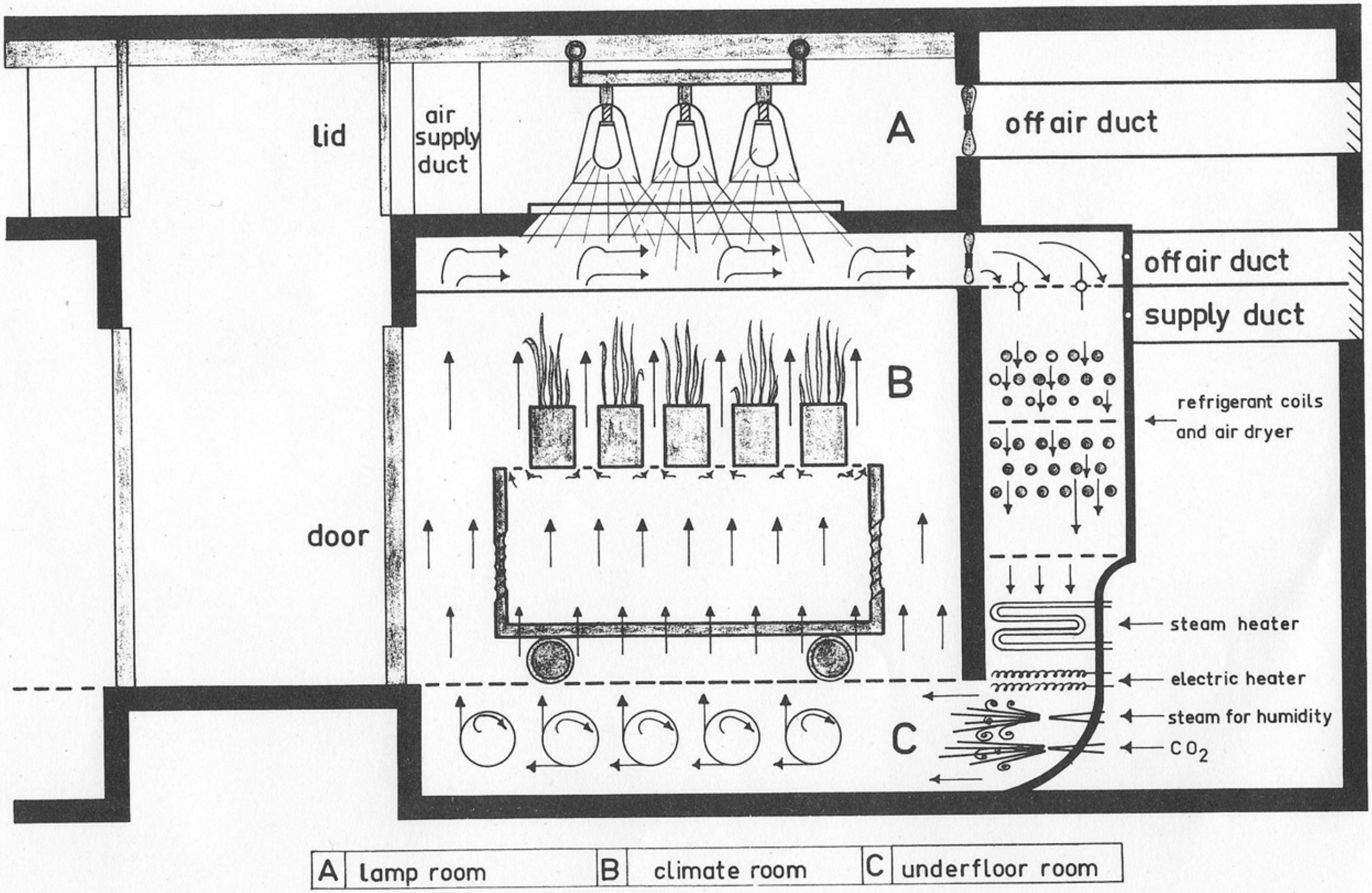


Fig. 4 .- Cross-section of a chamber. Principle of air-conditioning.

Fig. 5 .- View into a chamber. Oats of different nitrogen supply.

Fig. 6 .- Lamps installed at a car, drawn out of a lamp-room.

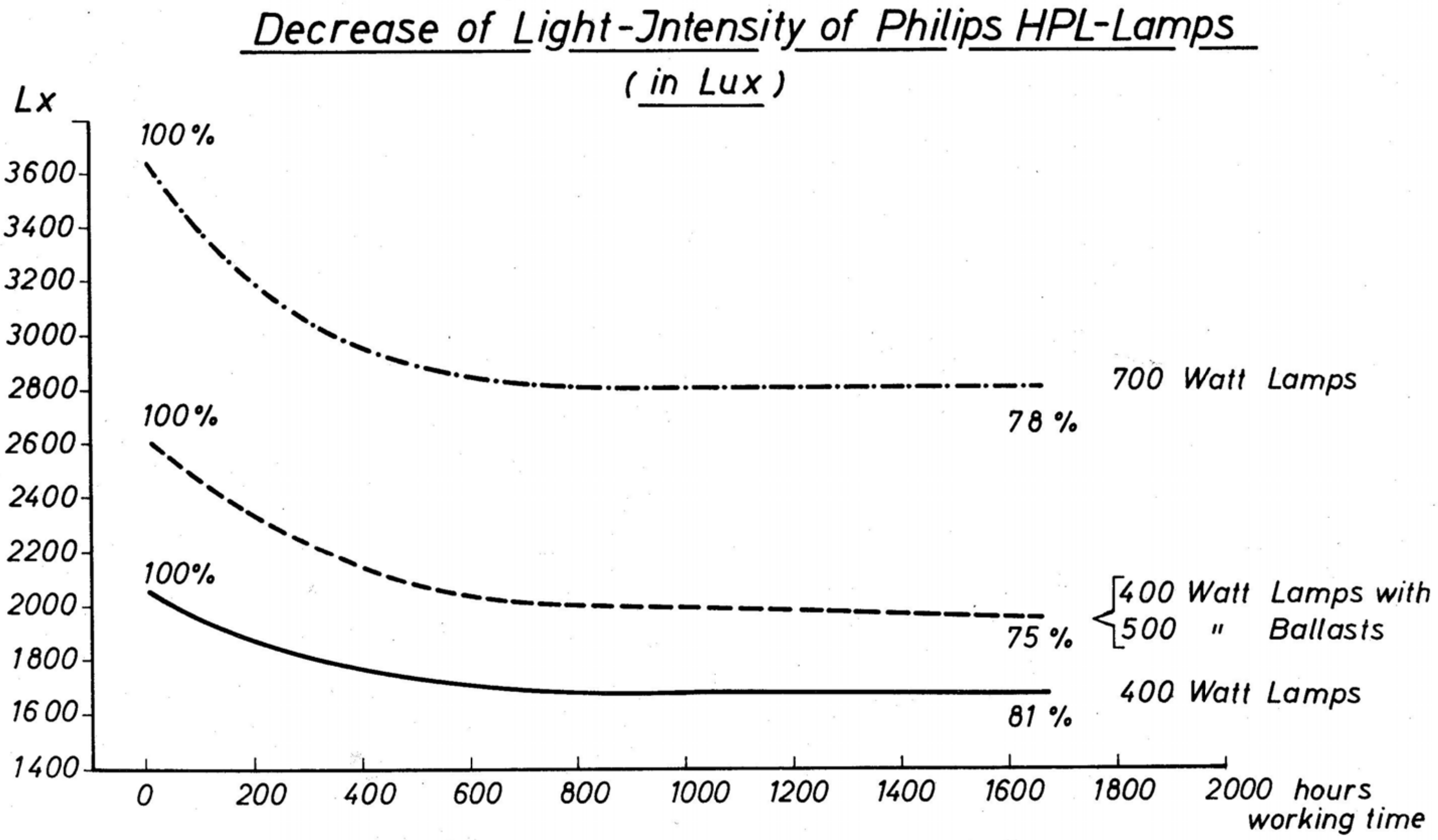


Fig. 7 .- Decrease of light intensity of mercury-highpressure-lamps (Type "Philips HPL").

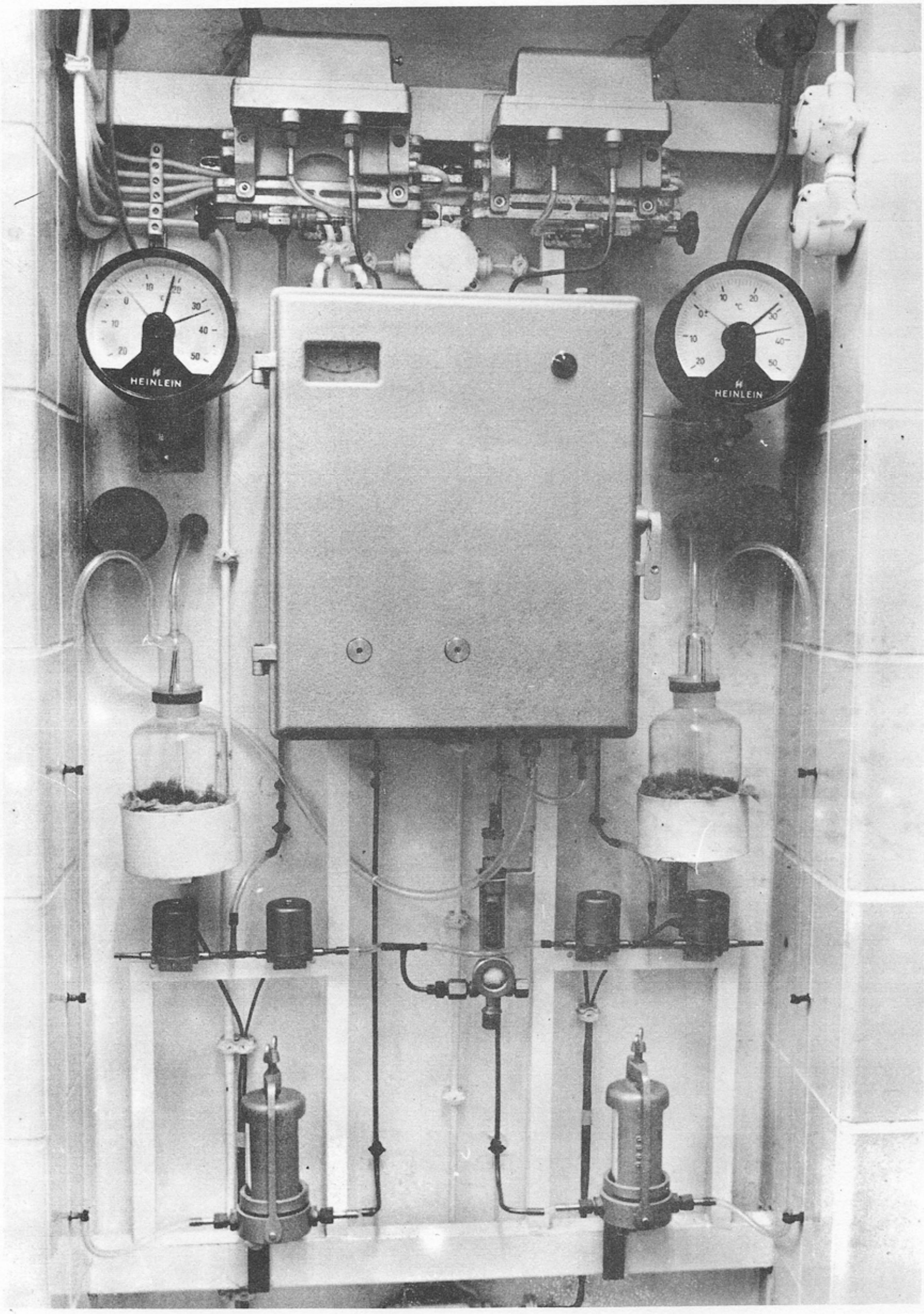


Fig. 8 .- Infra-red measuring-system for CO_2 control ("Uras").

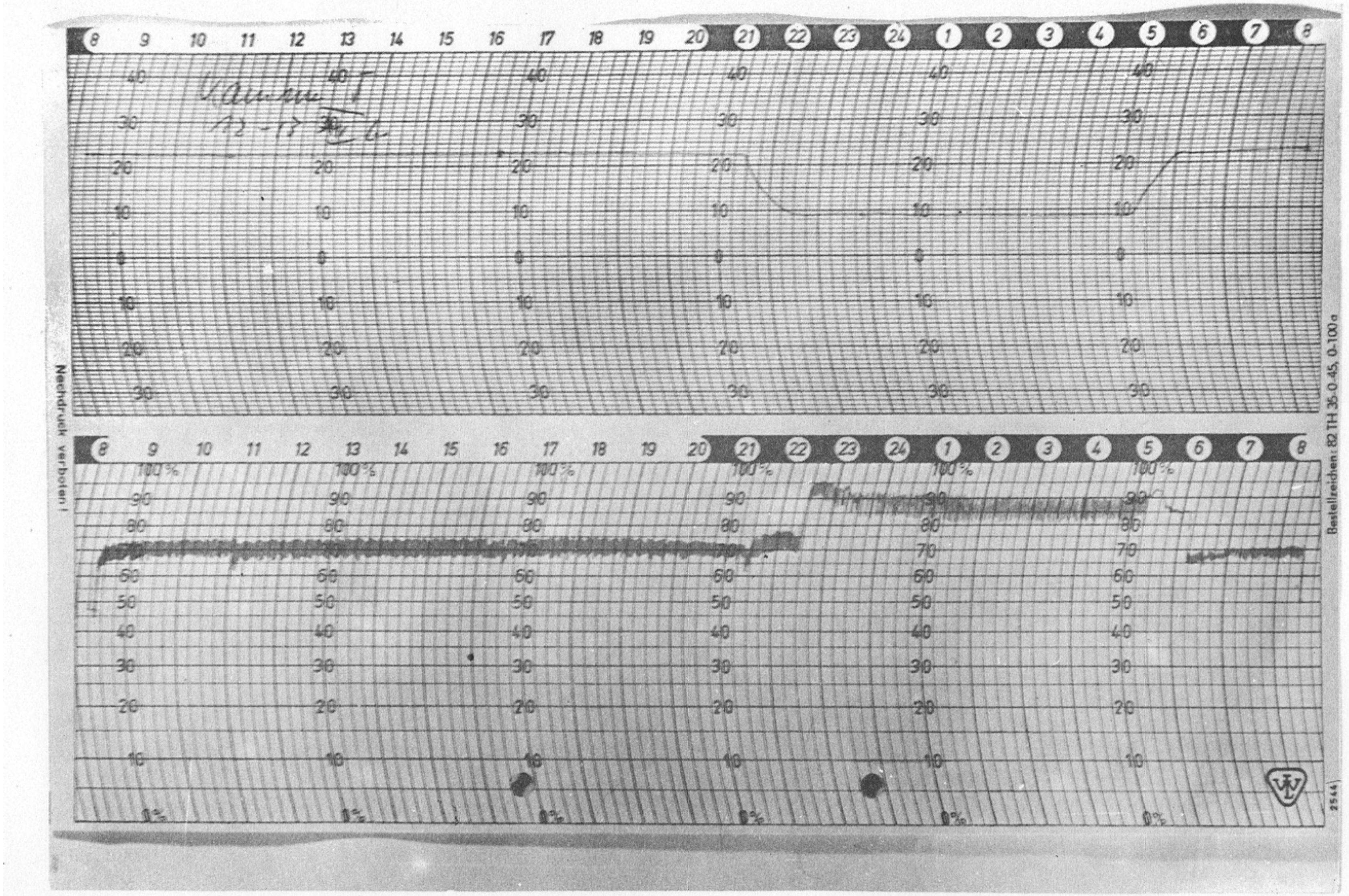


Fig. 9 .- Thermohygrograph-diagram showing the curve of temperature -and humidity-regulation in a climate chamber.

DESIGN OF CLIMATIC PROGRAMS IN PHYTOTRONES

by

Dr B. BRETSCHNEIDER-HERMANN

from the Institute of plant-Breeding and Plant-Cultivation of the Justus Liebig-University
of Giessen- Director : Prof. Dr E.V. BOGUSLAWSKI.

Experiments to learn the influence of climate on plant development, plant growth and yield under outside conditions must be carried out over many years. The single year in a temperate climate never has conditions, which can be said they are significant for a certain region. There are too much climatic factors, which con vary and two years with nearly equal temperatures will have other rainfall, other air humidity, other ligh' intensities, hours of sunshine etc...

Therefore we are constructing phytotrones to have reproducible, constant and controlled climatic conditions. It now may depend on the purpose of the experiment to design the climate program more or less similar to average outside conditions. But in any case o simplification will be necessary. This is founded in the nature of a phytotron.

The experiments in the phytotron of the institute of plant-breeding and plant-cultivation in Rauisch-Holzhousen should be carried out with cereals, mainly oats, which were to cultivate from emergence to yellow-ripeness. Oats is a well known plant for pot-cultivation. Average yields and observations from the pot-station under natural climatic conditions are a good standard for the results from the phytotron-experiments. The base of the controlled climate in the chambers should be the average climate of Rauisch-Holzhousen. For this purpose it was the task to find out a suitable program and some results of the experiments are given in the following.

Daily periodicity :

To design a program for the phytotron meteorological dates of 15 years from the observatory of the experimental field were evaluated. Thus we got an average temperature for each 2 nd hour of a day, which on the other hand is the average of 5 days. Each pentode of the months April-September was evaluated in this way. Some results are given in fig. 1. The straight lines are the average daily temperatures of the 1st pentode of April, May, June, July and August, rising from April to July/August. The curves show that the daily course of temperature in each of the six demonstrated pentodes is nearly the same. There is no great difference whether the photoperiod is longer br shorter or days are cool or warm. This means that the daily thermoperiodicity must be about the same during the period of vegetation.

The problem is now how to determinate the effective day and night temperatures. Sunrise and sunset taken as limit to calculate these average temperatures give a difference of about 4-5°C.Only at the beginning of April we find a smaller difference of about 3°C (s.tob. 1).

WENT (1) is calculating the daily periodicity by the formula :

tnyc = t min 1/4 (t max - F min) and

tpho = t max - 1/4 (t max - t min)

In our climate this would give differences between day and night temperatures, which are slightly higher than those based on astronomical dates (see tab!. 1). In general there is a good correspondence between the two calculated values. On the other hand experiments showed that oats give better yields when the amplitude of day- and night- temperature is about 10°C. This difference is to find between the lowest and highest temperatures in the course of 24 hours os to be seen in fig. 1 and tab. 1. Some results to this question are given in tab. 2. There is no effect on straw-yields but the grain-yield is better on account of a higher 1.000 grain-weight. These better results of a larger day-night-amplitude (see fig. 2) were got although the vegetation was shorter.

An other question is to which time these day-and night- temperatures should become effective. There are two possibilities : to change the temperature with the beginningof the photoperiod or to change it at the point of inflexion of the daily curve of temperature (fig. 1 and 2). In the first case the night temperature during "summer", when days are long, would be given far a shorter time than in "spring". To keep the average 24 hour temperature it is not possible to have a constant difference of 10°C for thermoperiodicity , which on the other hand follows out of the course of daily temperatures as shown before. Some results of an experiment about the effect of always the same length of the photo-temperature compared with a length depending from the photoperiod are given in tab. 3. Slightly higher grain- and clear higher straw-yield were the result, although the vegetation-period from emergence to yellow-ripeness was longer and the ratio grain : strow lowered.

Furthermore the experiment should give an answer to the question to which extent the program should be adapted to the outside course of temperature.

it is possible to have only one nyctotemperature and one phototemperature. But the adaptation becomes better when there are more steps of temperature. As it was said, oats showed a positive reaction on more extreme temperatures in thermoperiodicity, the effect of two phototemperotures keeping the same average phototemperature was positive for yield too and this again means a greater difference between maximum and minimum temperature during one day. The results of this experiment are given in tab. 3 under 3rd. Now the ratio groin : straw again becomes better and mainly the 1.000-grainweight is higher. The length of the vegetation-period is again 115 days.

So we conclude for the problems of daily periodicity that experiments with oats bring good results if the amplitude of day and night temperatures is about 10°C. The length of the phototemperature must not vary with the lengthening of the photopericdbut may be constant as in nature. The effect of two phototemperatures is positive again and seems to be similar to that of a greater day-night-amplitude. An example for a design For such a program is given in fig. 2, 2nd program.

<u>Seasonal periodicity</u> : Generally seasonal periodicity is unders-tood os the requirement of chilling during winter to break dormancy. Oats are sown in spring and do not need a chilling in this sense. But in nature temperature rises from sowing time in spring to the end of July and then drops again. This is demonstrated in fig. 3. It is remarkable that an average of 15 years makes not disappear cool or warm periods and the smoothened curve has been calculated by interpolation.

It is sure that this course of temperature, starting low and becoming warmer and warmer, in the period of vegetation has an influence on development, growth and yield of plants, which are adopted to temperate climate.

Fig. 4 shows a design for temperature and doylength, which is based on these conditions enclosing the questions of daily and seasonal periodicity. There is a rising of the 24-hour average temperatures from Nee to five days from April (time of emergence) to June and dropping again from August (harvest time) to September. From these 24-hour temperatures each a nyctotemperature (t nyc) has been calculated which is about 6°C lower and has a constant length of 9 hours. The corresponding phototemperature (t pho) is calculated to keep the 24-hour temperatures and from this the two temperatures t pho of 11 hours and t pho$_{\text{n}}$ of 4 hours length are calculated. The length of phatoperiod (-discontinued line) has been calculated from astronomical dates including one hour of photoperiodic effective dawn.

Results of a pot experiment which amongst others hod this climate ore given in fig. 5. The average light intensity was 16.008 Lx. The Mitscherlich-pots were filled with pure sand and got a Fertilizing of 1,6 9N. The ratio N : K P was 1 : 1,2 : 0,27. Basic elements were added sufficiently. The results are averages of 3 repetitions. There were six harvest-times depending on development and growth :

I. at stage A
II.- at stage BI/BII
III.- at 35-40 cm high shoots
IV.- at heading
V.- 20 days after end of length growth (milkripeness)
VI.- at yellow ripeness

In fig. 5 the above designed temperature-program (Fig. 4) is to compare in its yields (chamber 5) with two other-program. In chamber 7 one pentode 4°C wormer than chamber 5 alternates with the next pentode 4°C cooler than that of the "normal" program. This has a positive effect on yields From on early stage of growing to yellow-ripeness. Especially a higher yield of grain is the result. If a "normal" period of temperature (from emergency to "DI is followed by a worm period ("D" - "A") after which cooler temperatures are effective ("A" - milk-ripeness), as it is schematically shown in the fig. 5, a yet higher is the effect, especially of straw, but this effect is last not least the result of a longer period of vegetation. It is also to see that the cool period has a retarding effect on development (times of harvesting are later) and in the beginning of the curve yields are lowered by the cool period.

The results show that a "seasonal periodicity" is not only of importance by breaking dormancy during winter but also for all stages of development and last not least for yield when the plant has reached the physiological ripeness. Of special interest is the fact, that in this case too alternating temperatures are of great importance for growing and yield of oats. It may be expected, tIra all crops adapted to the temperate climate, where cooler periods are alternating with warmer periods, will show the described positive reaction.

1) WENT, F.W. "The experimental control of plant growth". Chron. Bot. Comp. ,Waltham, Mass. U.S.A., 1957, p. 238.

TAB. I .-

Time of the day h	°C temperatures in each first pentade of April	May	June	July	August	
2	4,5	5,6	9,7	13,7	13,0	dark
4	3,9	5,1	8,9	12,8	12,3	
6	3,4	5,6	10,2	13,1	12,4	
8	4,7	8,4	13,2	15,4	15,2	
10	7,8	11,6	16,3	18,7	18,3	
12	10,4	14,5	18,1	20,3	20,6	light
14	11,4	15,5	19,3	21,7	22,0	
16	11,7	15,7	19,7	21,6	22,4	
18	10,8	14,8	18,9	21,5	21,4	
20	8,3	11,8	15,3	19,7	18,1	
22	6,8	9,1	12,3	16,1	15,5	dark
24	5,4	7,6	10,7	14,6	14,1	
24^h average	7,4	10,4	14,3	17,2	17,1	
night "	5,8	7,8	10,9	14,8	13,7	based on astr.datas
day "	8,6	12,3	15,5	19,0	18,8	
Diff.day-night	2,8	4,5	4,6	4,2	5,1	
night average	5,9	7,7	11,6	14,6	14,8	based on formula WENT
day "	9,7	13,1	17,0	19,5	19,9	
Diff.day-night	3,8	5,4	5,4	4,9	5,1	

TAB. 2 .- Pot-experiment with oats P X/62. Soil : pure Sand, nitrogen : 1,6 g/pot.

	Yield g/pot grain	straw	total	ratio grain : straw	length of veg.-per. days	1.000 grain-weight g
Amplitude day-night = 5°C	16,9	61,8	78,8	0,27	124	12,8
Amplitude day-night = 10°C	27,4	62,8	90,2	0,43	117	16,4

TAB. 3 .- Pot-experiment with oats PVIII/62. Soil : pure Sand, nitrogen : 1,6 g/pot.

	Yield g/pot grain	straw	total	ratio grain : straw	Veget. days	1.000 gr.-weight
1.-1 day- 1 night-temp., lenght of day-temp.corresp.to photoperiod.	33,2	49,8	83,0	0,67	115	20,0
2.- 1 day- 1 night-temp., daytemp. const. 7,30 h. to 22,30 h.	34,9	58,7	93,6	0,59	122	19,5
3.- as before, but 2 phototemperatures	33,2	51,9	85,1	0,64	115	22,0

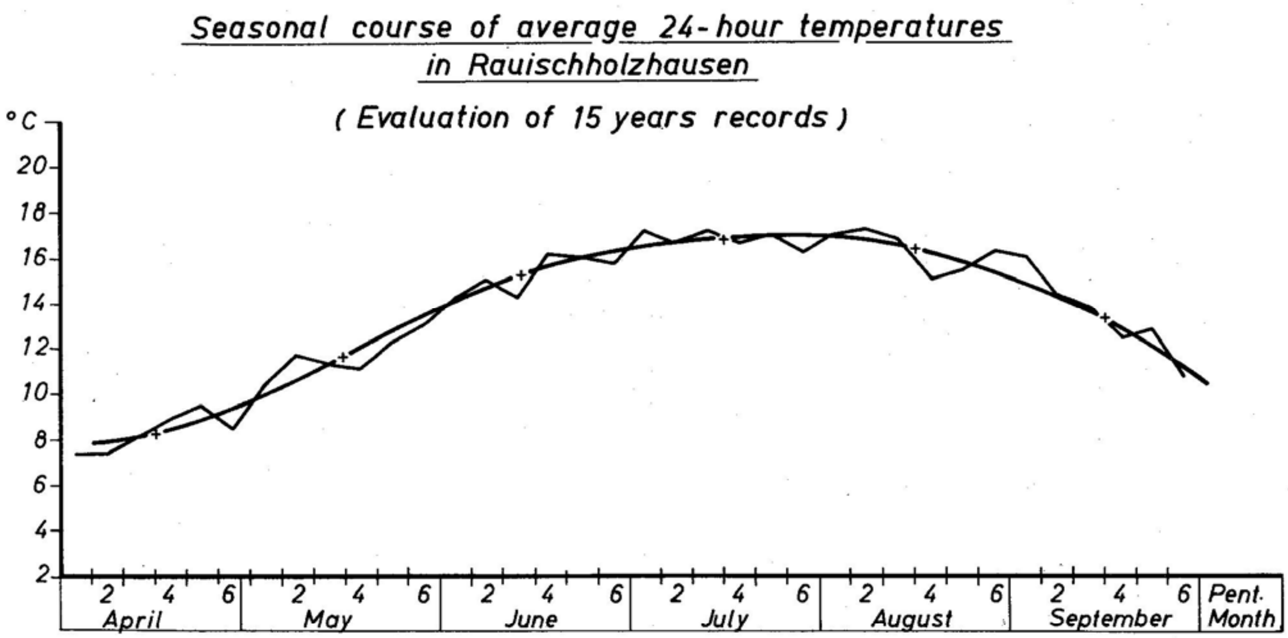

Seasonal course of average 24-hour temperatures in Rauischholzhausen
(Evaluation of 15 years records)
°C
20
18
16
14
12
10
8
6
4
2
2 4 6 April
2 4 6 May
2 4 6 June
2 4 6 July
2 4 6 August
2 4 6 September
Pent. Month

Fig. 3

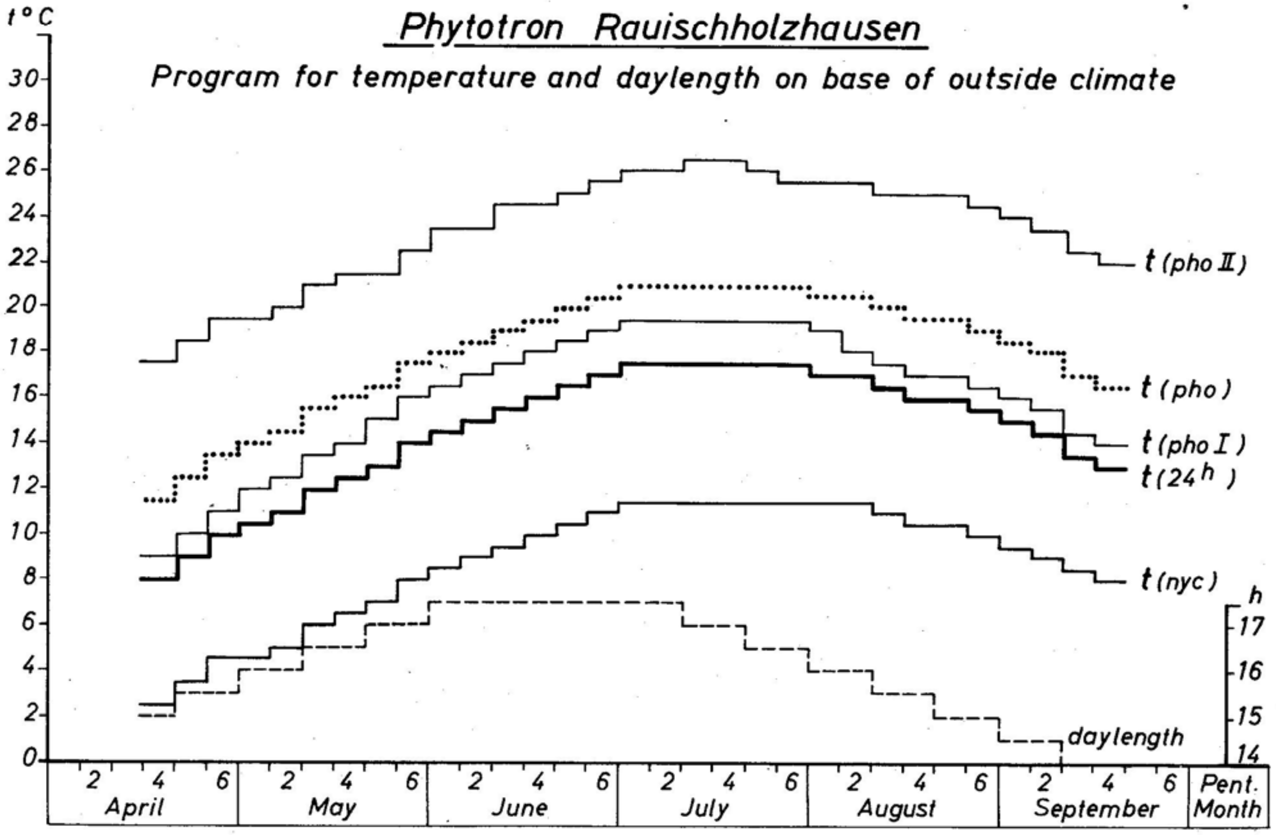
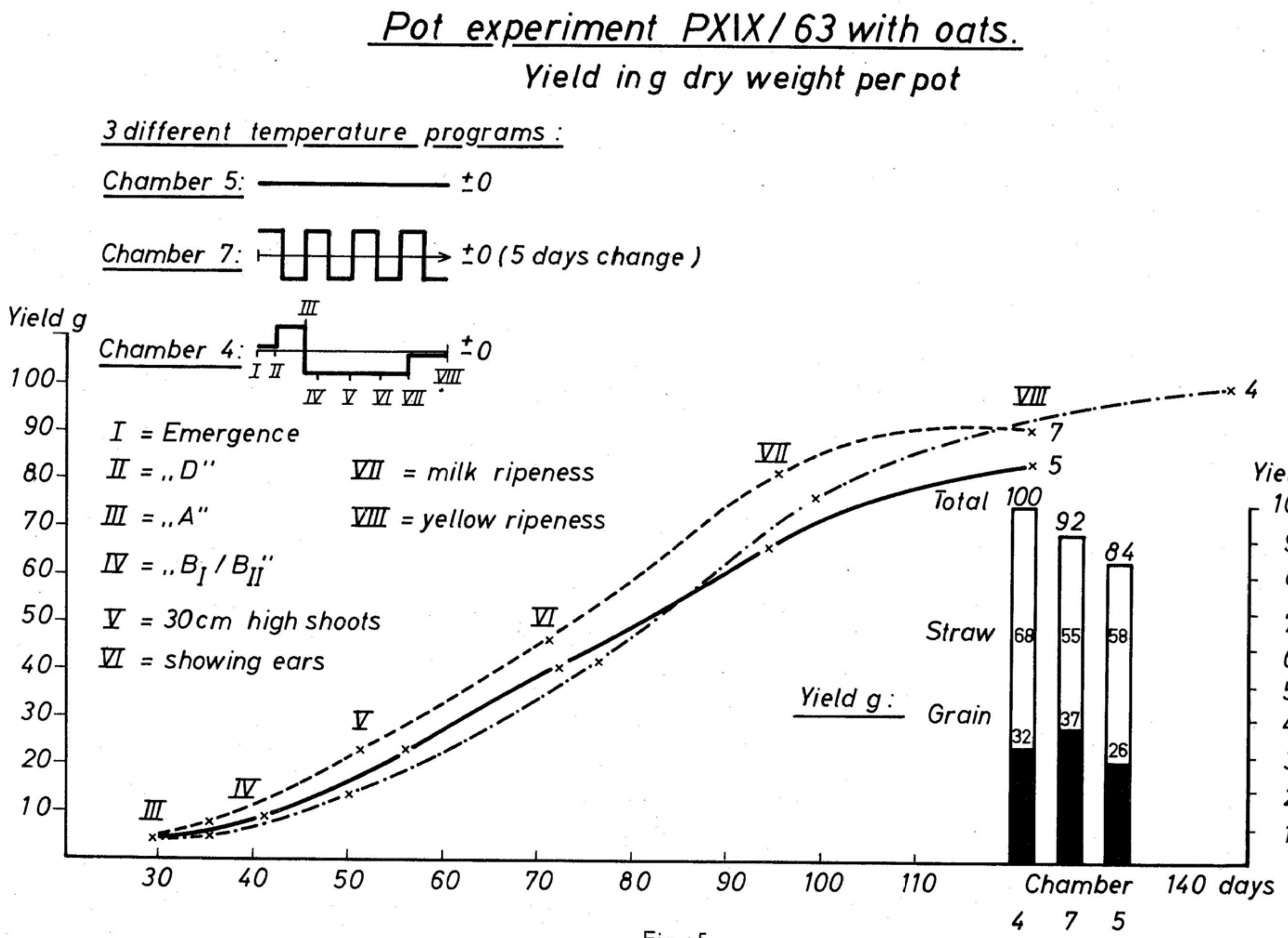

t °C
Phytotron Rauischholzhausen
Program for temperature and daylength on base of outside climate
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
t (pho II)
t (pho)
t (pho I)
t (24h)
t (nyc)
daylength
h
17
16
15
14
2 4 6 April
2 4 6 May
2 4 6 June
2 4 6 July
2 4 6 August
2 4 6 September
Pent. Month

Fig. 4



Pot experiment PXIX/63 with oats.

Yield in g dry weight per pot

Fig. 5

THE INFLUENCE OF CLIMATIC GRADIENTS ON PLANT-GROWTH IN AIR-CONDITIONING GREENHOUSES

by

Dr W. BOTTLAENDER, Biologisches Inst. der Farbenfabriken, Leverkusen.

The Biological Laboratories of Farbenfabriken BAYER in Leverkusen, Germany, ma intain several air-conditioning greenhouses. The plants grown in these greenhouses are used to test the effects of pestizides, fungizides and insectizides. They mainly are tomatoes, beans, cucumber, cotton and rice.

The plants should attain, independent from season and climate uniform quality and size or leaf size and the desired maturity should be reached after growing periods of three to four weeks.

In order to reach these conditions, every effort was made to keep the gradients of climatic variables such as air temperature, air humidity, **velocity** of air and solar-light radiation at a minimum.

The first air-conditioning greenhouse has been built after the well-known pattern and was equipped with heating and cooling systems and ventilators. Its eight (8) chambers have a wall length of five (5) or ten (10) meters respectively and a depth of seven (7) meters.

It was found, however, that the building as well as the equipment, despite the fact that they were most complete and rather costly, did not fulfill the requirements altogether. Air temperature, humidity and circulation were not as uniform as desired.

In order to satisfy the steadily growing demand for air-conditioning greenhouses for their Biological Institute, the BAYER Co. in Leverkusen developped the so-called Ventilation Boxes.

A ventilation box consists of a rectangular glass duct with a spray nozzle installed inside this duct, forming a jet. A small amout of water is injected through the nozzle, but this carries a large amount of air along, that thus gets cooled and moistened at the same time.

Fig. 1 .- Shows a cross-section through an air-conditioning chamber, using a ventilation box, that is installed in the outer wall of the chamber. It can be tipped to both sides of the wall, so that air can be sucked in either from the outside or from the inside or even a mixture of both, which is then blown into the space underneath the table. The spray water evaporates there and the incoming air mixes with the air inside the chamber. This air mixture rises at the end of the table with a very low speed and slowly moves over the length of the table. Its circulation over the plants is very much like the natural air circulation in the open field.

Fig. 2 . - Shows the wall of an air-conditioning greenhouse equipped with ventilation boxes. As a result of the use of this new device, it was not only possible to considerably reduce the construction as well as the maintenance costs of air-conditioning greenhouses, but also to reach an important improvement of the uniformity of the climatic zones.

Fig. 3 .- Shows a cross-section of the distribution of climatic factors over a table. The distribution of climatic Factors vertical to the direction of air circulation over the table with of 1,6 meters was observed on a day with average

solar radiation and was Found to be as follows:

Air temperature : 21,6 + 0,2°C
Air humidity : 87,5 + 2,5 % relative humidity
Air circulation speed : 13 $^{+3}$ cm/sec
Average daily radiation : 0,14 + 0,012col per cm min-1

Temperature and humidity were measured with an aspiration-psychrometer, the speed of air circulation with a hot wire, the indicated value is the average taken from a series of seven (7) measurements. The solar radiation was determined with the solarimeter.

Despite the fact that the variation *of* these climatic factors was found to be relatively low, compared with previous results, obtained in a greenhouse without ventilation boxes, differences in the growth of neighbouring plants were observed.

These differences were investigated for the 19 (nineteen) then existing chambers. The curves of plant-growth for neighbouring plants for these 19 chambers were practically identical and basically the same results were obtained in a series of growing periods.

Fig. 4 .- Shows the curve of plant-growth for a stand of cotton plants, which was intentionally sown very thickly. it is apparent that the differences in growth are not very big. By no means did they affect the purpose of the experiment. But the fact that such differences did occur at all seemed to justify further investigations which may eventually lead to a method of eliminating these differences.

It is rot very likely that these differences in growth of neighbouring plants were caused by differences in those growing conditions as soil, watering or even genetic differences. The differences in air temperature and humidity are so small that they can rightfully be neglected, whereas radiation and air velocity show appreciable variations. These two factors together cause the more or less important deviations of the temperature measured on individual parts of the plant against the temperature of the surrounding air.

We started from the hypothesis, that the determination of a temperature value, representing the factors which influence the plant temperature would be highly useful in investigating the problem.

This reasoning led to the development of a measuring element, consisting of a bent piece of sheet silver with a soldered thermo-element. The temperature of this measuring device is depending upon air temperature, air velocity and light radiation, just as the temperature of the plants. A relationship to the air humidity can be neglected, since the occuring differences in humidity changed the average plant temperature by less than 0,1°C.

In the following, the temperature of this measuring element will be called complex-temperature or model-temperature.

It was found to be a value approximately in the middle between maximal leaf temperature and the temperature of the surrounding air, similar to the temperature of the bud.

The first measurements were made in 1960 with cotton plants.

10 (ten) cardboard pots, containing five (5) plants each, were lined up with equal distances on a cram-section line within a group of cotton plants. The model-temperature was measured regularly with the silver-element, starting from the moment of leaf formation until the termination of the experiment. Simultaneously, we measured the temperature of a horizontally situated piece of leaf with the aid of very fine thermo-elements as well as the temperature of the soil surface with the aid of resistance-elements.

The solar radiation could only be measured after the plants were harvested. These results were then compared with the radiation on socalled typical days - i.e. (that is) days with similar variation of solar radiation - and thus the radiation for the entire experimental period could be calculated.

The experimental results are shown on Fig. 5.

It was not possible to discover a direct relationship between stem-length, wet weight, dry weight or relative dry weight on one side and one of the environmental factors on the other.

It was then tried to find a relationship between plant-growth and several environmental factors at the some time. This calculation led to four (4) regression-polynomes. The threshold of significance of the significant factors was hold on 10 %. The regression polynomes and the significant environmental factors are described as follows.

Plant Growth Characteristics dependent on Significant Environmental Factors

y_1 = Stem Length
y_2 = Wet Weight
y_3 = Dry Weight
y_4 = Relative Dry Weight

Significant Environmental Factors

x_3 = Average Daily Maximum of Leaf Temperature
x_4 = Average Daily Value of Model Temperature
x_6 = Average Daily Maximum of Model Temperature
x_7 = Average Solar Radiation
x_8 = Average Daily Value of Soil-Surface Temperature
x_9 = Average Daily Maximum of Soil-Surface Temperature

Regression-Polynomes

$$
\begin{aligned}
y_1 = {} & 125{,}5 + 2{,}4\,(x_3 - 28{,}7) + 6{,}3\,(x_6 - 30{,}7) \\
& + 1248\,(x_4 - 21{,}4) - 28{,}93\,(x_4^2 - 458) \\
& - 17130\,(x_7 - 0{,}14) + 59510\,(x_7^2 - 0{,}01958) + \xi\,1
\end{aligned}
$$

$$
\begin{aligned}
y_2 = {} & 1{,}669 + 20{,}65\,(x_4 - 21{,}4) - 0{,}469\,(x_4^2 - 458) \\
& + 0{,}087\,(x_6 - 30{,}74) - 0{,}218\,(x_9 - 25{,}7) + \xi\,2
\end{aligned}
$$

$$
\begin{aligned}
y_3 = {} & 0{,}218 + 9{,}05\,(x_4 - 21{,}4) - 0{,}2106\,(x_4^2 - 458) \\
& + 0{,}0092\,(x_6 - 30{,}74) - 90{,}72\,(x_7 - 0{,}14) + 301{,}7\,(x_7^2 - 0{,}001958) \\
& - 0{,}0475\,(x_8 - 21{,}21) + 0{,}0567\,(x_9 - 25{,}7) + \xi\,3
\end{aligned}
$$

$$
\begin{aligned}
y_4 = {} & 13{,}04 + 417{,}2\,(x_4 - 21{,}4) - 9{,}788\,(x_4^2 - 458) \\
& - 5271\,(x_7 - 0{,}14) + 1723\,(x_7^2 - 0{,}001958) \\
& - 2{,}24\,(x_8 - 21{,}21) + 5{,}49\,(x_9 - 25{,}7) + \xi\,4
\end{aligned}
$$

The degree of certainty is for

$y_1 = 96,4$ %
$y_2 = 87,7$ %
$y_3 = 99,6$ %
$y_4 = 97,5$ %

These figures ore only of relative value, since, for example, the climatic fluctuations, which have an important influence on the plant-growth, could not be taken into consideration as yet.

The average model-temperature is of paramount significance in all regression polynomes. Its effect is linear and quadratic. Furthermore, the average light radiation and the maximum soil temperature have a great influence.

The graph showing the regression lines Makes the relationship between environmental Factors and plant-growth very obvious.

The upper half of Fig. 6 shows the stem-lenght of the plant at the end of the experimental period as a function of the model-temperature with constant radiation and leaf temperature. The model-temperature has an optimum : this means that under constant radiation the stem-lenght increases with increasing temperature up to a certain degree of temperature, beyond which this relationship is inverse. Using the maximal model-temperature os a parameter causes a parallel shift of this curve. The stem-length is increasesif under the some average model-temperature its maximum lies higher. This could very well be the effect of an occasional radiation maximum.

The lower half of Fig. 6 shows the influence of solar radiation. If the radiation is too low, the plant grows very tall, the growth decreases with increasing radiation, it reaches a minimum after which it increases again with still increasing radiation. The parameter in this relationship is the maximal leaf temperature.

The upper of Fig. 7 shows that the wet weight depends upon the average and maximal model-temperature in the same way as the stem length does. The optimal overage model-temperature, however, was found to be approximately 1/2°C higher.

The lower part of Fig. 7 shows that the wet weight decreases with increasing maximal temperature of the soil surface.

The first graph on Fig. 8 shows that the wet weight too depends upon the average and maximal model-temperature.

The second graph on Fig. 8 shows, that the dry weight decreases with increasing average temperature of the soil surface. The temperature of the soli surface is controlled by the following Factors

- Amount of radiation reaching the surface.
- Amount of heat absorbed by the surrounding air. -

Heat used in evaporation of soil humidity.

The last two factors show a variation in the region of low air velocity, which is proportional to this velocity. The parameter in this graph is the maximal soil temperature, the increase in soil temperature effects an increase in dry weight.

The relationship between dry weight end average temperature of the soil surface should not really be explained in such a way, that the plant growth appears as a function of the temperature of soil surface. Quite on the contrary, it should be made clear that the plant growth or the amount of shadow provided by *the* plant controls the temperature of the soil surface. From this we can conclude that the temperature of the soil surface cannot be used as a suitable factor providing reproducible experimental conditions.

The third or last graph on Fig. 8 shows, that, under the so for investigated environmental conditions, the dry weight decreases with increasing radiation.

The curves on Fig. 9 representing the relative dry' weight, are similar to those already discussed. The maximum, however, appears at lower average model-temperature than it did for the other factors, influencing plant growth.

The foregoing experiment was repeated in the following year. in order to gain additional information, it was **now** tried to measure the air temperature with the aid of shaded thermo-elements. The previously used silver-elements were now replaced by platinum-elements to make sure that the radiation qualities of the surface were not changed during the experiment due to oxydation. The solar radiation during the experiment was measured with solarimeters, lined up parallel to the plants but behind them in the direction of air circulation.

The results were taken from the continuously measured values during the daytime only, since, as we knew already from the first experiment, the temperatures at night are almost the some for all plants.

For this second experiment, we took the soil temperature measured near the plant roots, whereas the temperature of the soil surface was considered For our first experiment.

The climatic fluctuation during this second experiment was entirelydifferent from the one encountered during the first test.

The results can therefore not agree numerically.

Fig. 10 gives a numerical as well as a graphical representation of the regression polynomes of the relative dry weight for both experiments.

It can be *seen* from this figure, that the model-temperature is of paramount significance for both regression polynornes. It enters the results linearly and by the square.

The highly radiation-controlled maximal temperature of the sail surface appearing in poly-name I is replaced by the maximal radiation in polynome II. It should not be concluded, however, that a factor not appearing in the regression polynome cannot have any influence. it could very well be that the only reason that such a factor. did not appear is the fact, that its variation was too small to be noticeable. The curve'showing the regression line for experiment II nicely fits the respective curve for experiment I after it has been shifted parallel in a permissible manner.

Regression calculations have been carried out for all other factors describing plant growth for this second experiment. The results very much resemble those obtained during the first experiment.

The air temperature, however, could not stand up against the model-temperature at all. **It** obviously responds to the radiation despite the fact that the measuring element was shaded. The soil temperature near the roots was more or less identical for all plants. Thus, its influence could not be determined. The maximal leaf temperature, which was significant during the first experiment, showed no influence at all during the second one.

It was also examined, whether the determination of values with the aid of typical days was

Bis

permissible. The result was positive. The variation of measured values remains basically unchanged, if the days are selected and classified carefully.

From the degree of variations observed for even a very limited section out of a stand of plants, it can be concluded, that the influence of numerous factors on the plant growth can be determined from a single experiment and within a relatively short period of time. As an example we may take the variations of the model-temperature from one plant to another, which amounted to approximately 0,1°C.

It is true, that with this method, only small ranges of environmental factors are under experimental control. Yet, this has the advantage, that the possible variations of existing relationships can be closely watched for individual ranges. Obviously, the mathematical function describing curve-section I must be different from the one applicable for curve-section II.

The experimental procedure, where the influence of a single factor is investigated while all the others remain constant, does not appear to be reasonable. This is particularly true due to the fact, that in most artificial light growing rooms the variations of environmental factors are *of* the some order of magnitude as those used For our regression calculation.

The assumption, that a set of values measured at a certain representative location is applicable to the entire stand at plants, is a simplification, that leads ***to*** the loss of considerable amount of information and makes the reproducibility of experimental results very doubtful. It follows, therefore,that this simplification is not permissible.

The main cause For this variation of environmental factors is the difference in radiation. The radiation reaching the plant is transformed into heat or water evaporation, both of which inscrease the heat content of the circulating air.

The exchange of energy between plants and circulating air is subjected to the very same physical laws, that are valid in the technical realm for energy conversion. Whether we consider ***the*** principles ***of*** direct- or counter current, whether the stream of air or water moves ***alongside*** or across the pipes or plates, their dimension and number -all these facts are important for efficiency and resistance, for the circulation characteristics and for the gradients of energy carriers.

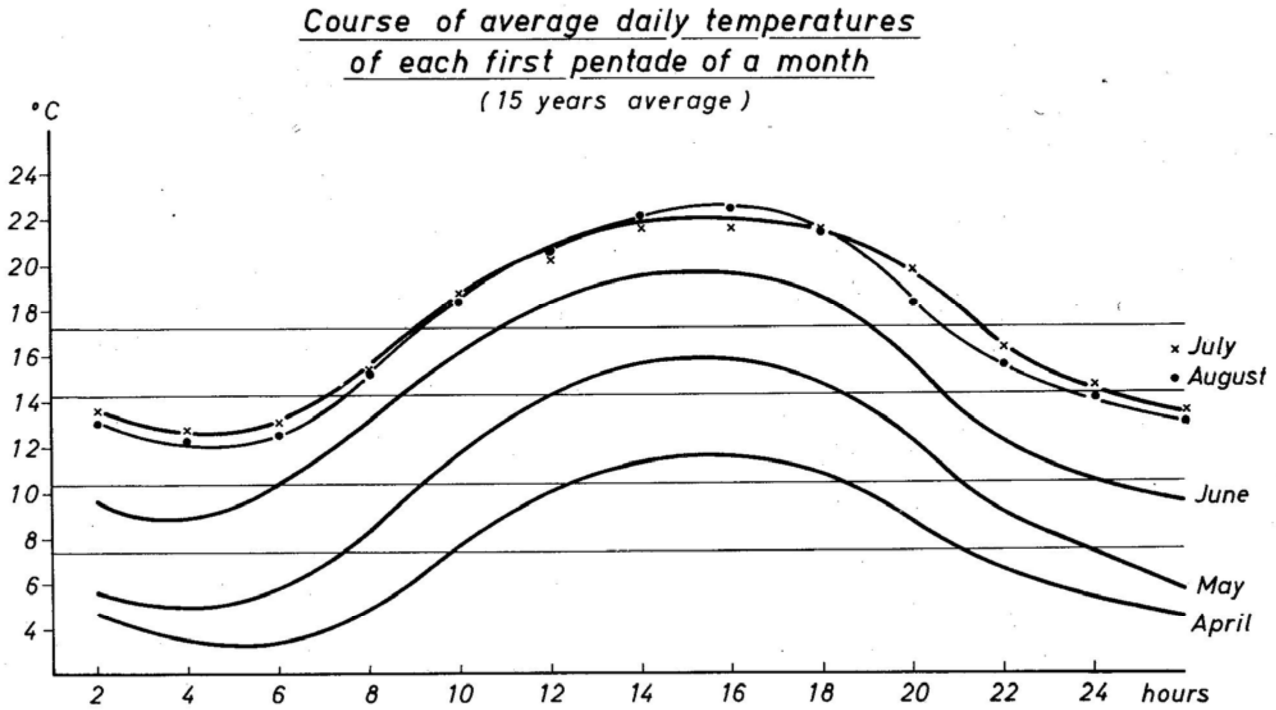
Since air circulation and energy ***transformation*** are inevitable facts, the construction of an artificial light room with constant temperature *and* humidity of the air as the energy carrier, remains entirely utopia. Even in a tightly closed artificial light room with unmoved air, the light will immediately cause a thermal air circulation.

Shape, construction material and dimension of an artificial light room and also the arrangement of the plants just a vitally influence the gradients of environmental.factors as light and air circulation.

Reproducible experimental results can only be obtained in identical artificial light rooms with identical plant arrangement. It is therefore necessary to standardize the artificial light rooms and to numerically define the density of plant stands for each experiment, since the density of stand has an extraordinary great influence on the plant growth.

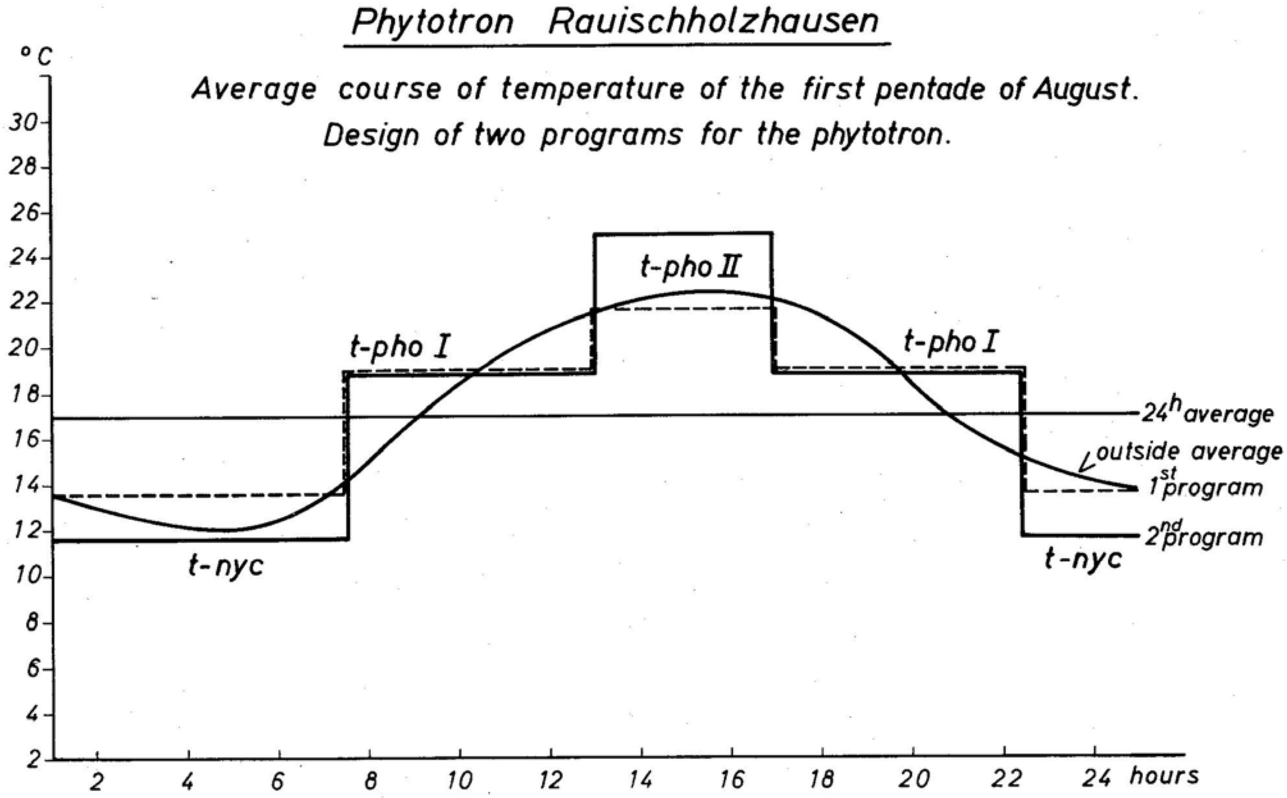
The gradient of environmental factors can be changed by charring the density of stand. The outskirts of a plant group, where the environmental factors can have the entire range of intermediate values between the surrounding climatic conditions and the climatic conditions of the stand, should be a preferred subject For investigations. This would at the same time bring some light into the relationship between surrounding climatic conditions and climatic conditions at the plant. This knowledge is a necessary tool For investigations with individual plants under natural growing conditions.

The evaluation of each experiment took approximately six .(6) months, mcinly For the deter-


Course of average daily temperatures of each first pentade of a month

(15 years average)

Fig. 1


Phytotron Rauischholzhausen

Average course of temperature of the first pentade of August.

Design of two programs for the phytotron.

Fig. 2

mination of average valves with the aid of a planimeter.

This extensive task would become unnecessary, if the zones of environmental factors in the artificial light rooms could be so adjusted, that the applicable values for all possible plant locations could be defined in advance and were known for each experiment.

Experiments in air-conditioning greenhouses and in the open field still require continuous measurements of environmental factors at the specific plant location.

In order to shorten the process of evaluating the curves printed by the compensation printers, we designed an apparatus that calculates the hourly and daily totals as well as the amplitudes of the daily maximum and minimum semi-automatically within five (5) minutes and prints these results on a printing roll.

This device makes it possible, to have the entire results, including regression calculation available one week after the termination of the experiment.

The regression analysis was carried out by our Department far Mathematics with the aid of a computer. The evaluation apparatus was built in our fine-mechanical work-shop.

Aso result of these investigations, we arrive *at* the following conclusions :

1) Variations of environmental conditions, that are so small, that they can hardly be measured, still have an apparent and unmistakable influence on plant growth.

2) The curve of plant growth within a group of plants can only be described with the aid of an entire group of simultaneously active environmental factors.

I hope that the thoughts expressed in the foregoing may stimulate the further improvment of the already highly advanced technique of phytotrons and may draw your attention to the usefulness of an increased application of refined physical measuring methods on stands of plants as well as on standardization *of* plant growth chambers.

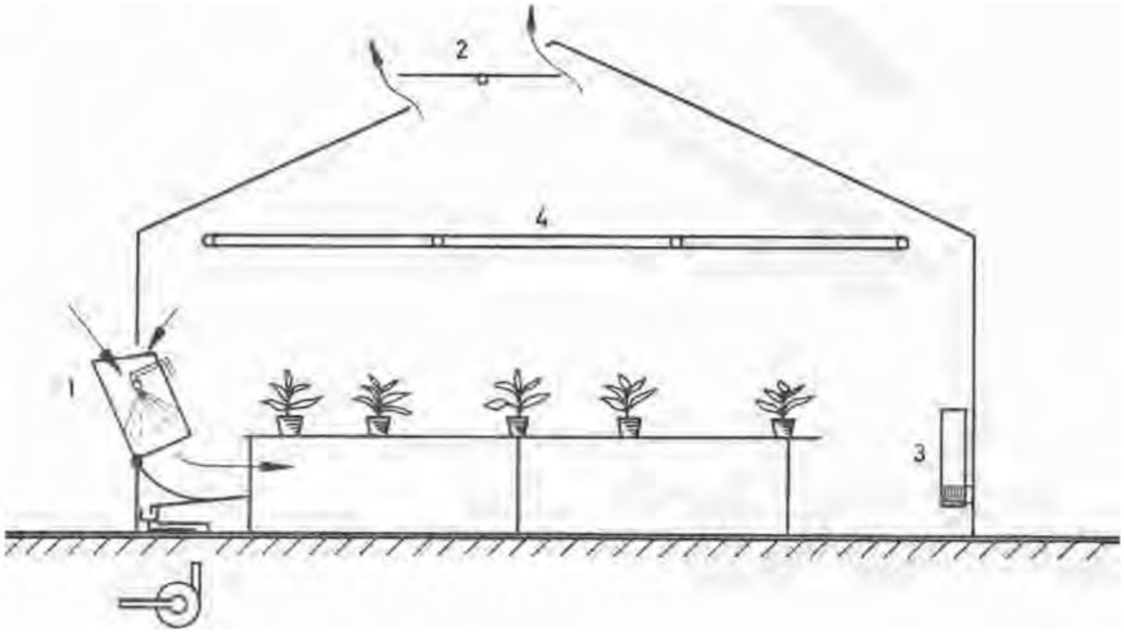


Fig. 1 .- Cross-section through an air-conditioning chamber.

Fig. 2 .- The wall of air-conditioning greenhouse equipped with ventilation boxes.

Fig. 8 .- Distribution of climatic Factors over a table.

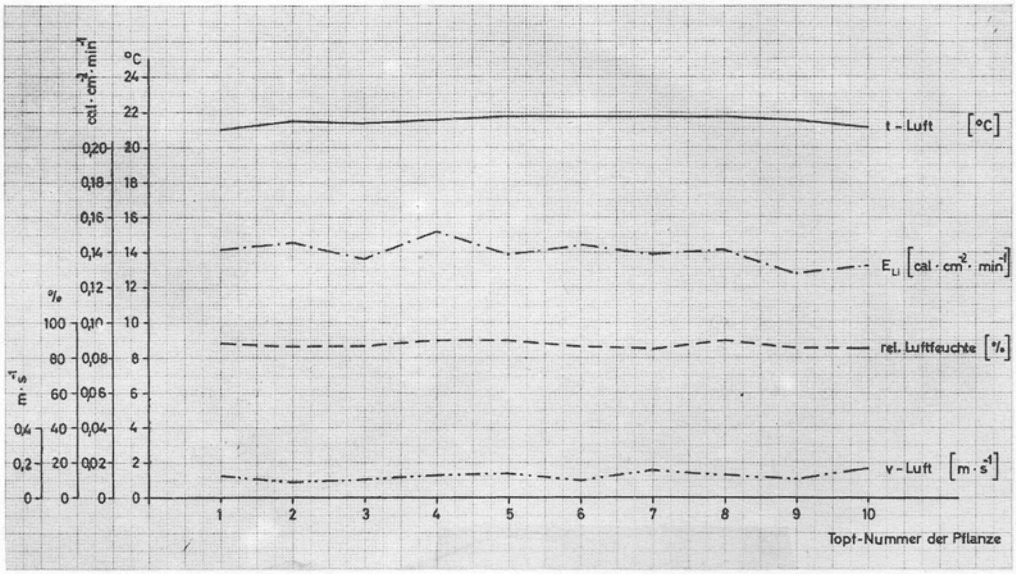


Fig. 4 .- Curve of plant-growth for a stand of cotton plants.

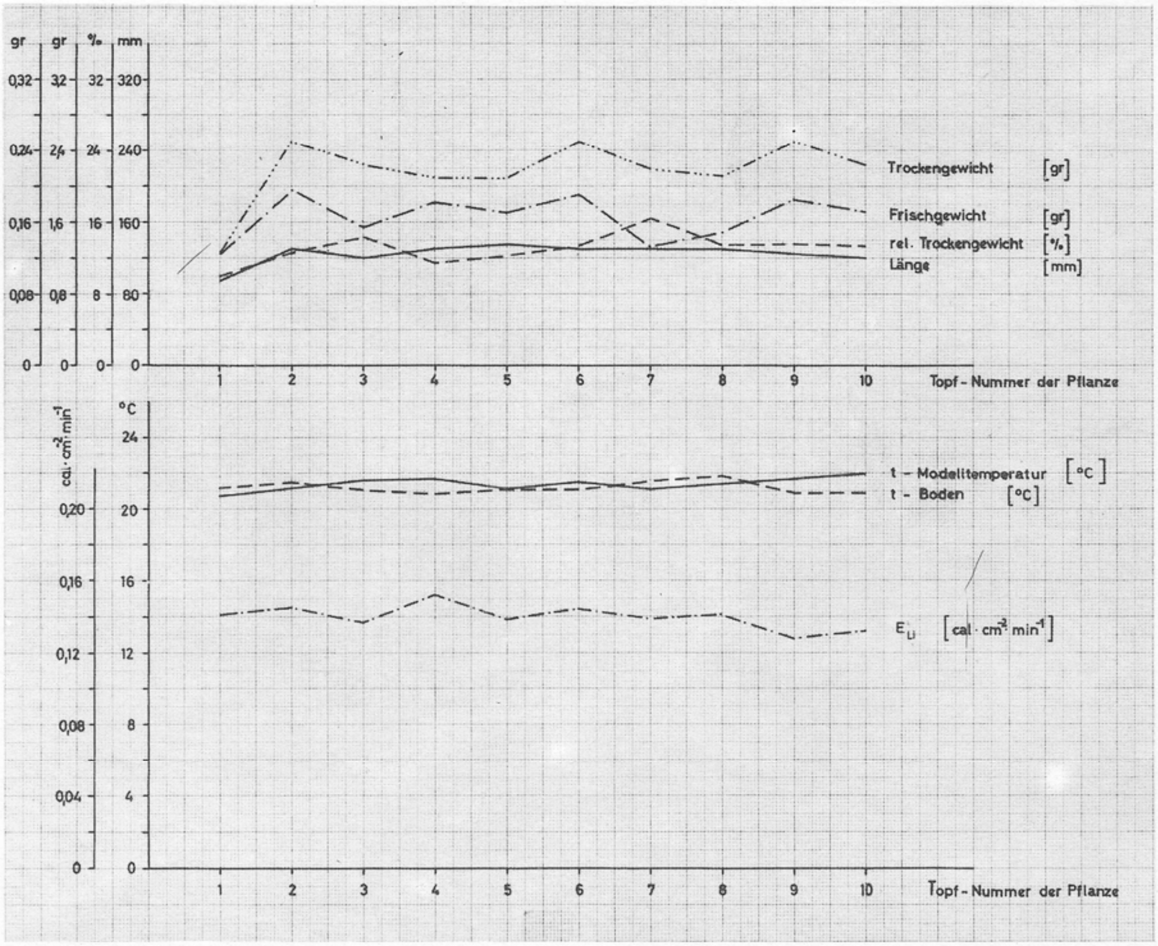


Fig. 5 .- Experimental results of "typical days" measurement.

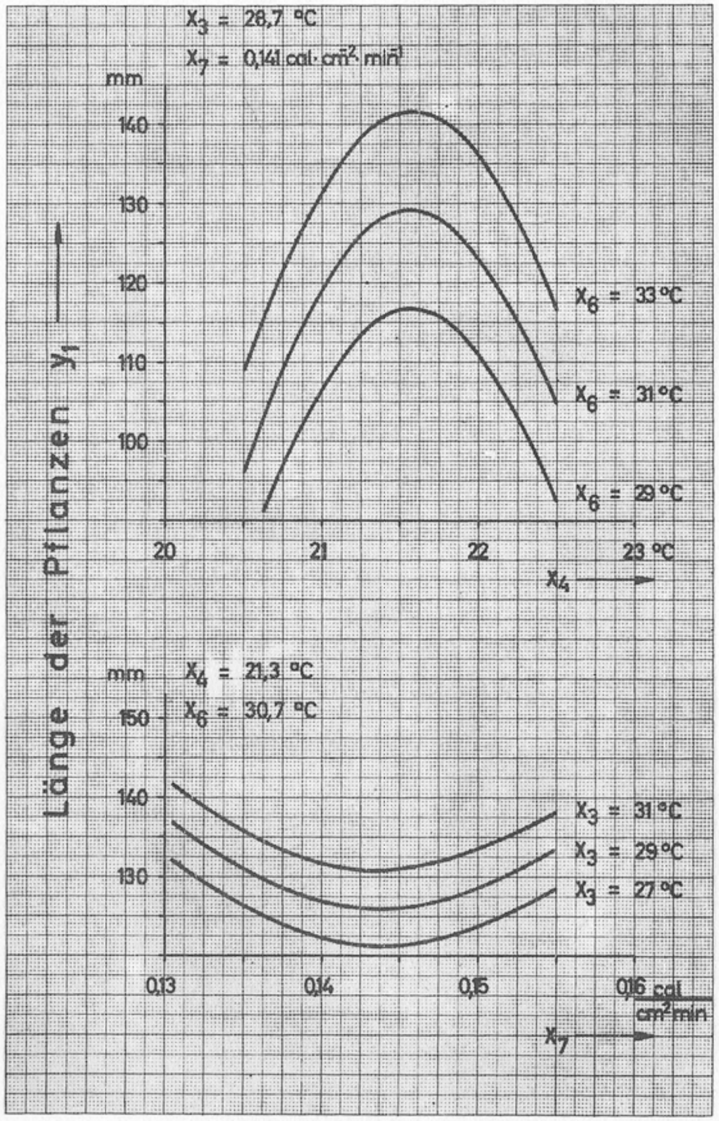


Fig. 6 .- Stem-length of the plant (upper) and influence of solar radiation (lower)

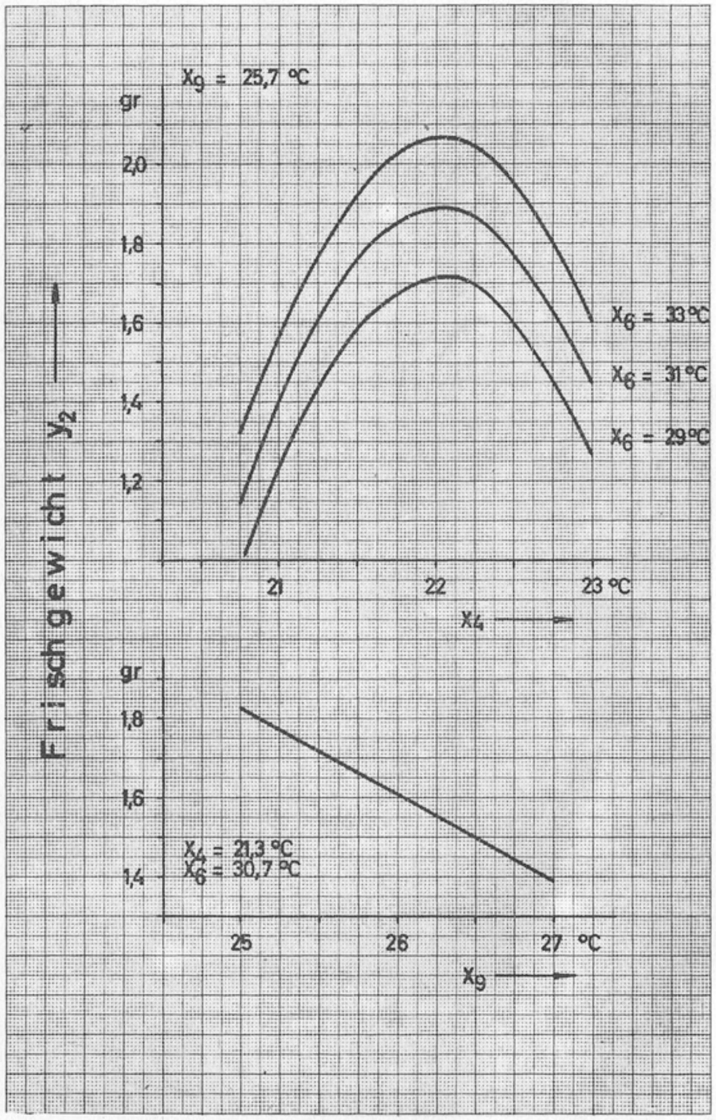


Fig. 7 .- Wet weight (upper) and relation with model-temperature. The wet weight (lower) decreases with temperature of soil surface.

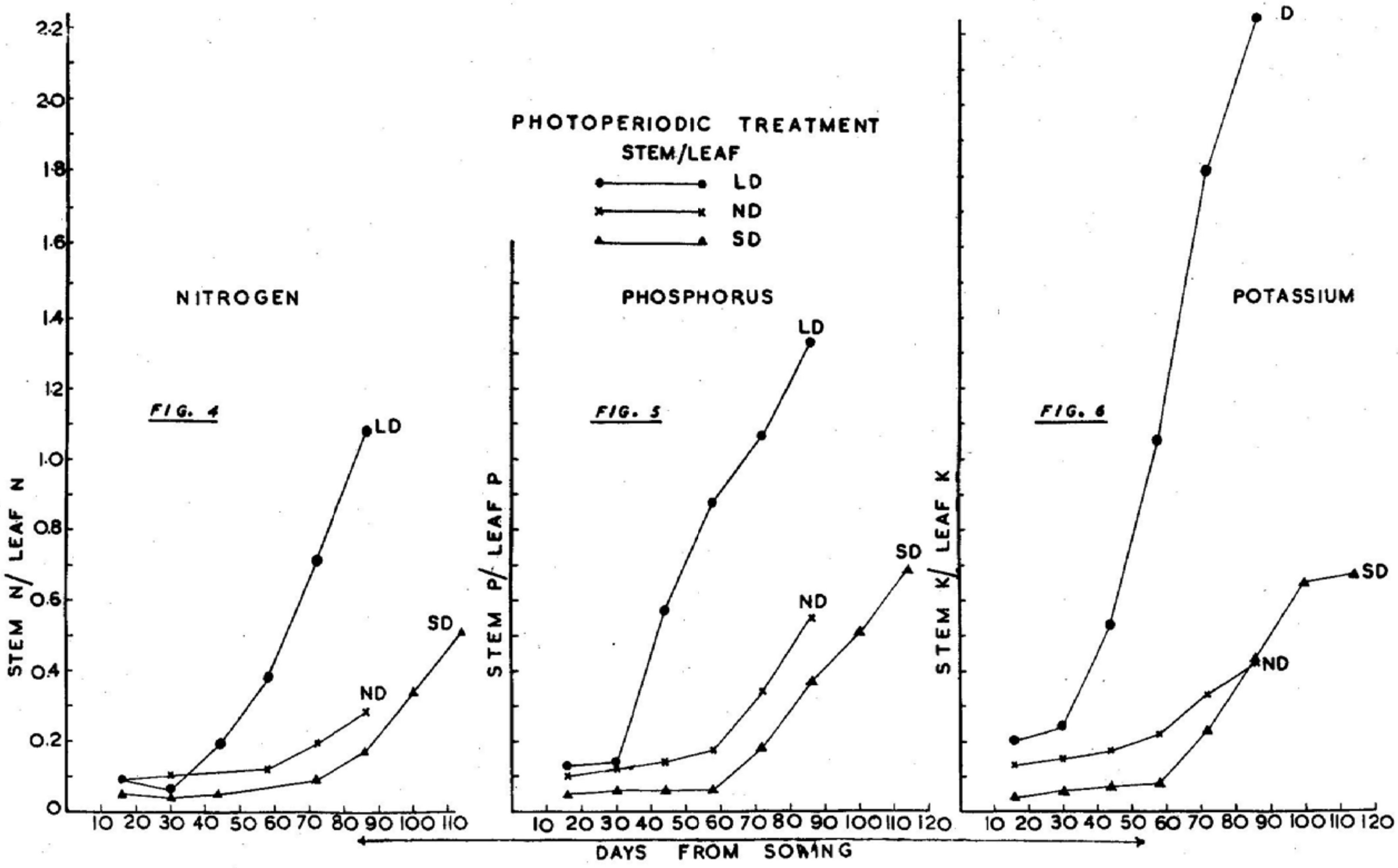


Fig. 3 . - Effect of photoperiodic treatment on stem/leaf ratio of nitrogen phosphorus and potassium at successive stages of growth. Data from Nanda, Chinoy and Sawhney (18).

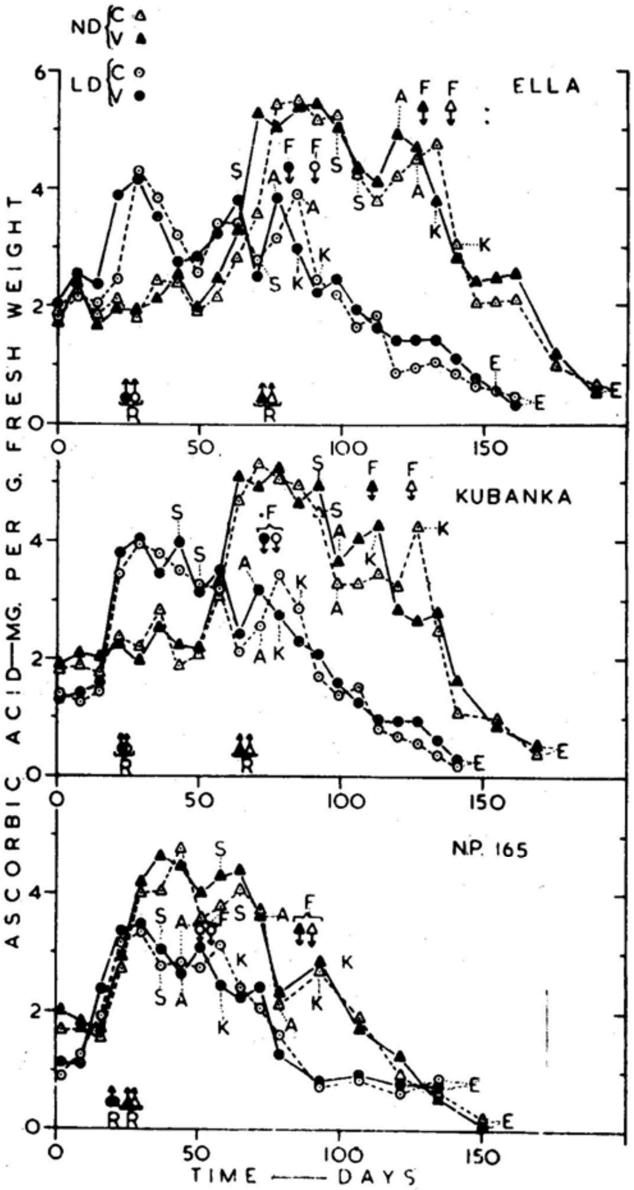


Fig. 4 .- Drifts of ascorbic acid in three varieties of wheat - Ella, Kubanka and N.P.165 - under four vernalization and photoperiodic treatments.

○ , Long day, unvernalized plants ;
● , Long day vernalized plants ;
△ , Normal day, unvernalized plants ;
▲ , Normal day, vernalized plants.

Arrows marked with 'F' indicate the time taken from sowing to anthesis and those with 'R' the time when maximum AA content is reached in each case. Data from Garg (19).

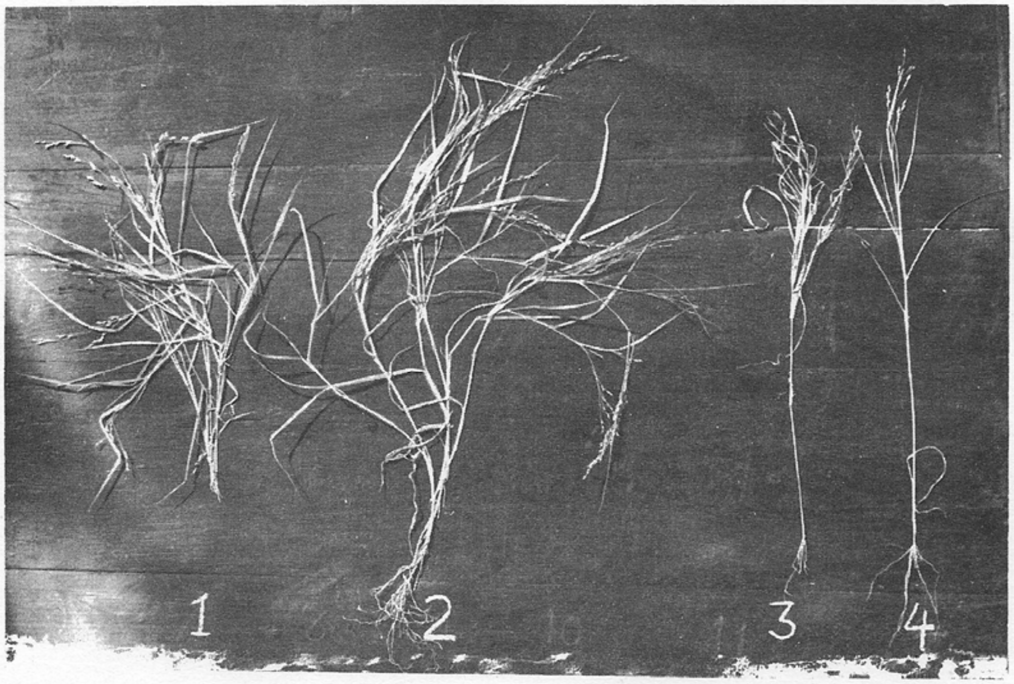
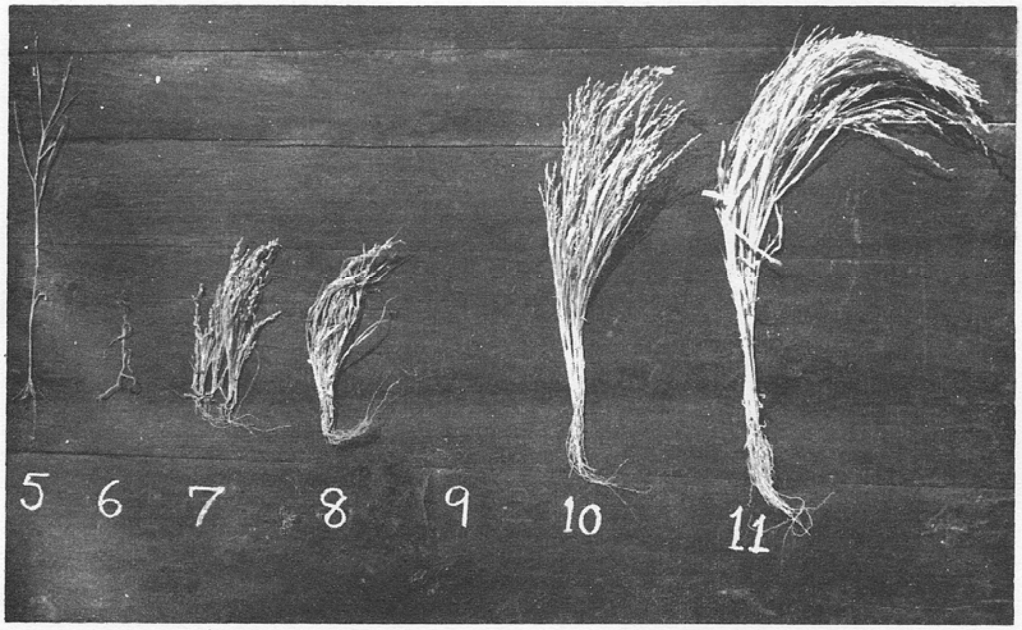


Fig. 5 .- Growth pattern of Panicum miliaceum in different sowings made at 32-day intervals throughout the year. First sowing was done in the month of April in Delhi. Data from Nanda (24).



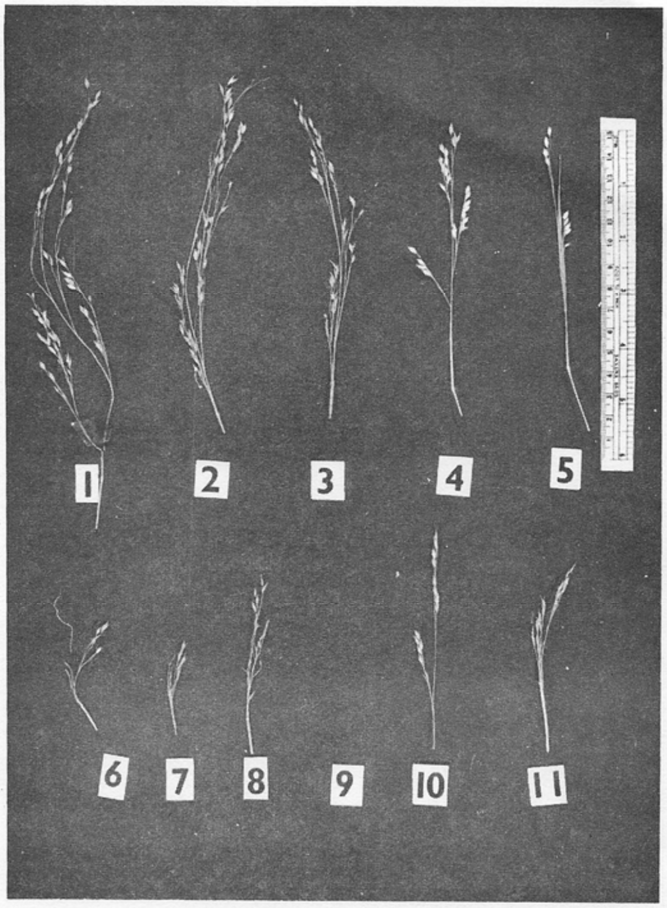


Fig. 6 .- Ears of Panicum miliaceum in different sowings made at 32-day intervals throughout the year. First sowing was done in the month of April in Delhi. Data from Nanda (24).

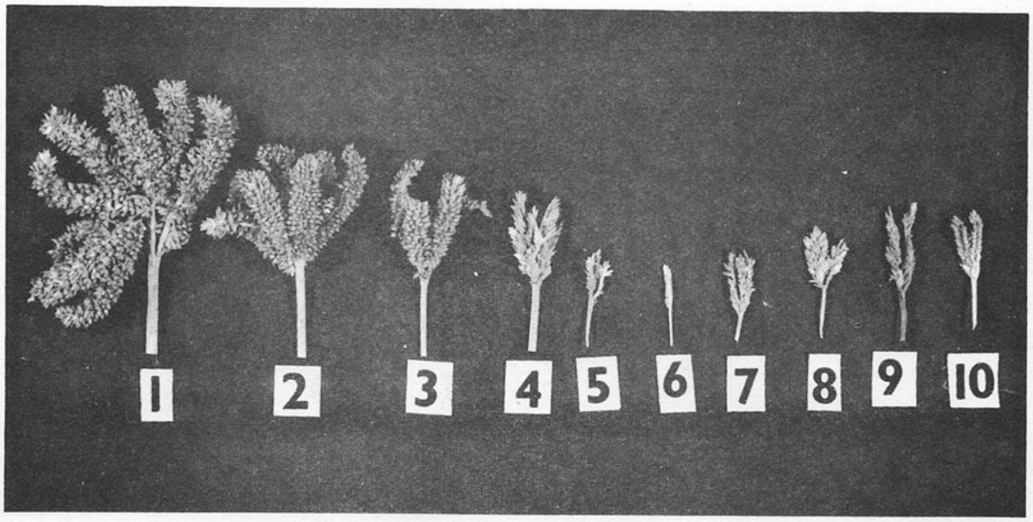


Fig. 7 .- Ears of Eleusine coracana in different sowings made at 32-day intervals throughout the year. First sowing was done in the month of April in Delhi. Date from Nanda (24).

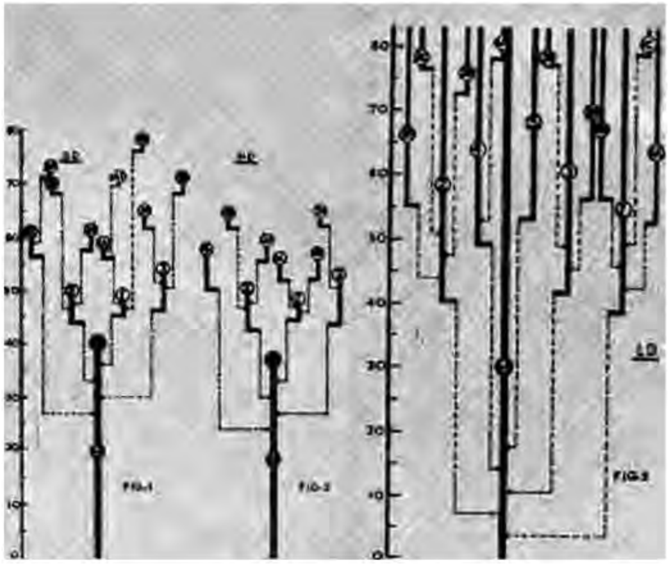


Fig. 8 Diagrammatic representation of SD, ND and LD plants the branches with the lengths of the vegetative periods of the main shoot and the branches Of different orders in Panicum miliaceum. The vertical colums represent the vegetative periods. The circles terminating these columns represent the inflorescence. The abscence of circles at the end of vertical colums, as in LD plants, indicates lack of flowering. The numbers within circles represent the order of emergence of branches and the position of the mode on the plant is indicated by an arrow that terminates below a dotted line which connects it with the main shoot in the case of primary branches and a primary branch in the case of secondary branches. Data from Nanda (25)

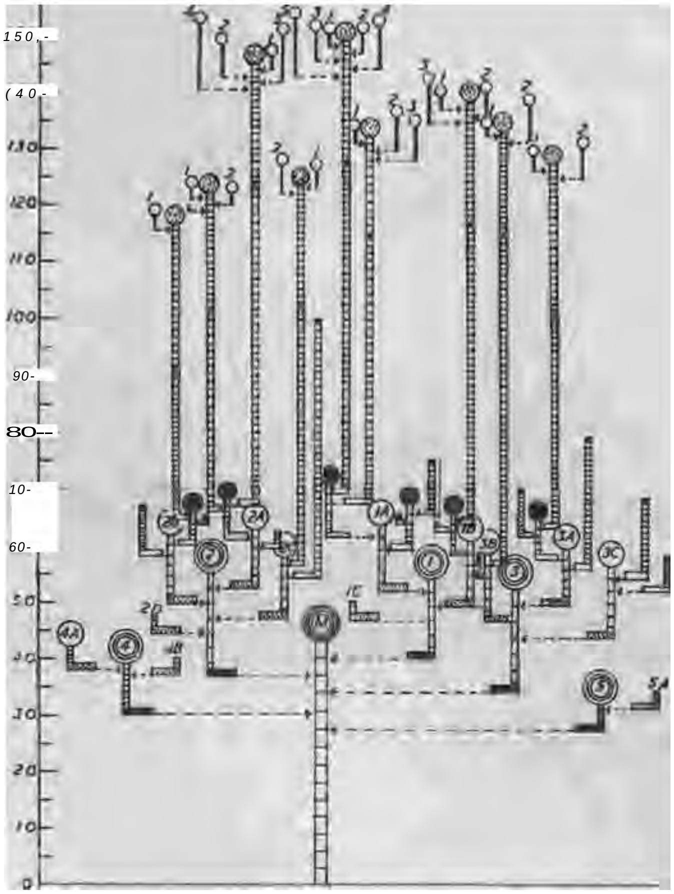


Fig. 9 .- Diagrammatic representation of a plant of Crotalaria juncea showing the number of branches and nodes as well as the height attained by the main shoot and branches of different orders. The vertical columns in this figure represent the height of the main shoot and the branches in cm. Data from Nanda (27).

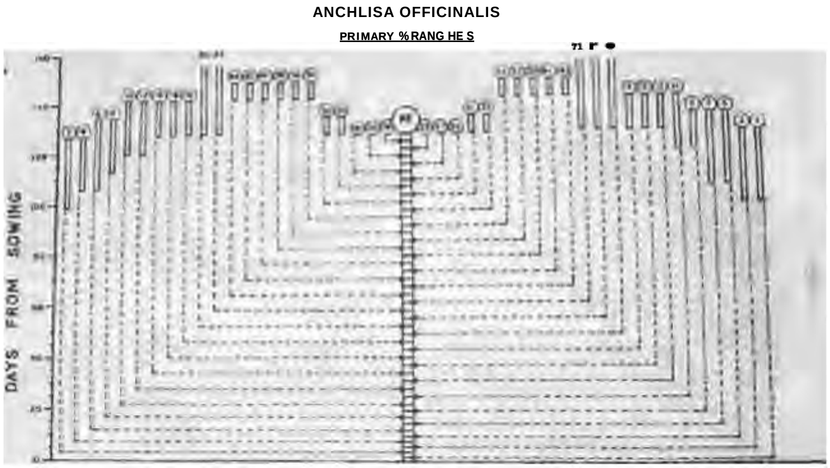


Fig. 10 .- Diagrammatic representation of a plant of Anchusa officinalis showing the number of primary branches as well as the lengths of the vegetative periods of the main shoot and ranches. The vertical columns in this figure represent the vegetative periods. The order of emergence of branches is shown by the numbers shown within circles which represent the inflorescence in each case. The absence of circles at the end of certain columns indicates that these did not flower at all. Data from Dhanraj (29)

Fig. 11 .- Effect of photoperiod on Impatiens balsamina. LDLD plants were sown under long day condition and were left there throughout the growing period. These remained vegetative and produced lateral branches in acropetal succession. NDSD plants were sown under normal day but were transferred to short day later. Lateral buds produced were reproductive. Data from Kumar (30).

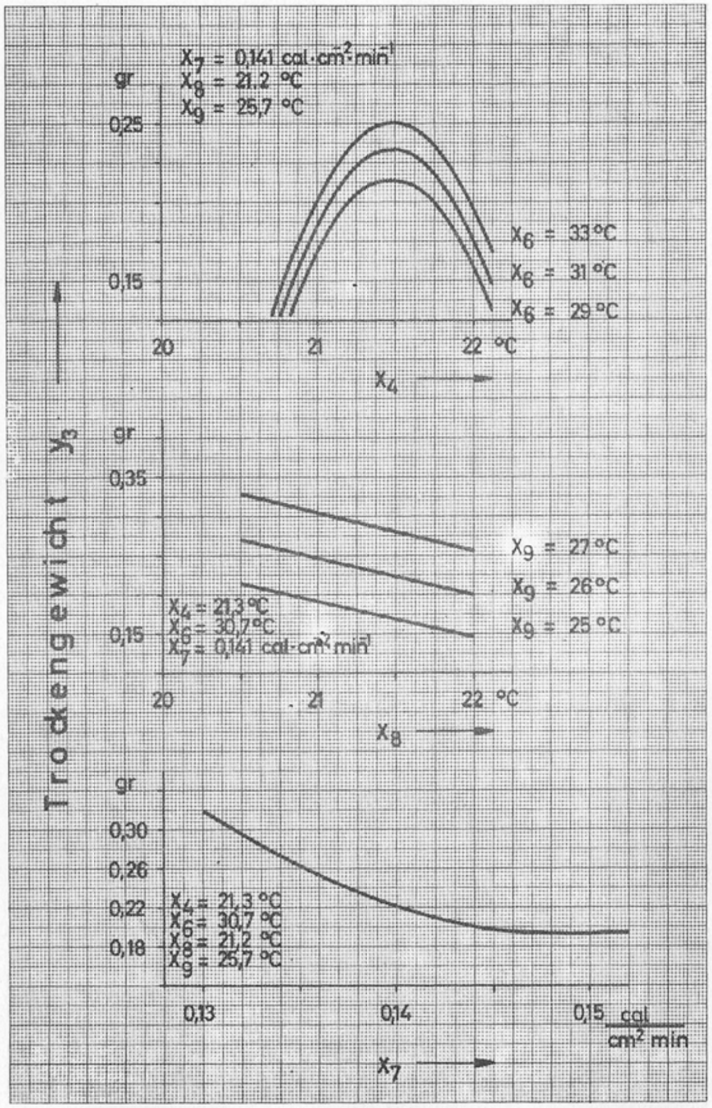


Fig. 8 .- Relation from wet weight and model-temperature (upper).
Relation from dry weight and temperature of soil surface (middle).
Relation from dry weight and radiation (lower).

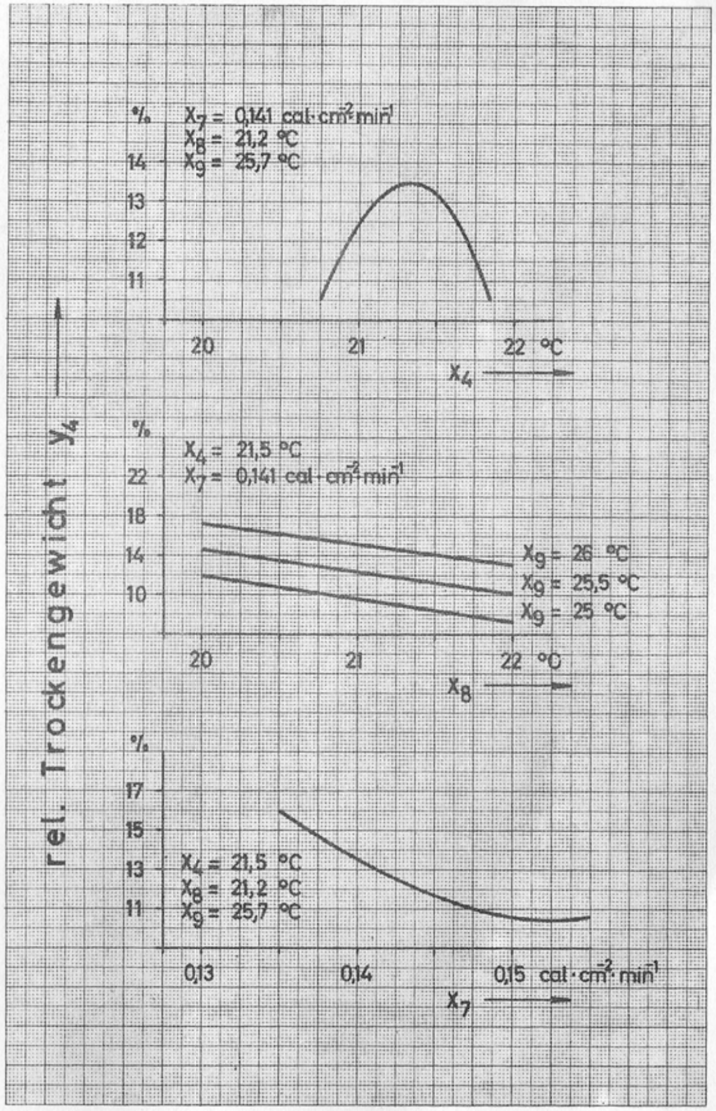
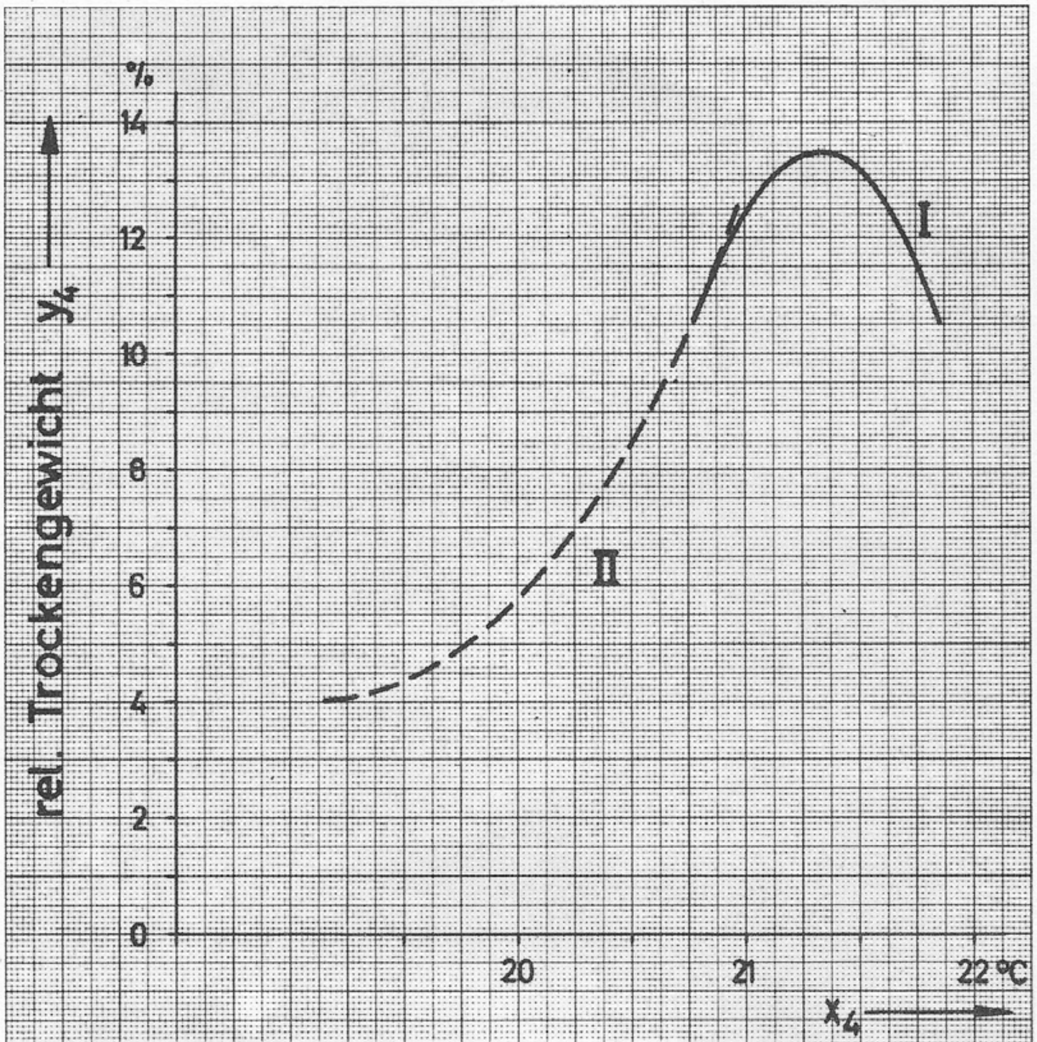


Fig. 9 .- Curves of relative dry weight of the plant.



I	II
$Y_{4\,I} =$	$Y_{4\,II} =$
13,04	9,210
$+ 417{,}2\,(X_4 - 21{,}4)$	$- 108{,}3\,(X_4 - 23{,}25)$
$- 9{,}788\,(X_4^2 - 458)$	$+ 2{,}46\,(X_4^2 - 540{,}9)$
$- 5271\,(X_7 - 0{,}14)$	$- 119{,}5\,(X_7 - 0{,}1457)$
$+ 1723\,(X_7^2 - 0{,}01958)$	$- 3{,}683\,(X_6 - 25{,}57)$
$- 2{,}24\,(X_8 - 21{,}21)$	
$+ 5{,}49\,(X_9 - 25{,}7)$	$+ 17{,}33\,(X_{10} - 0{,}555)$
$+ \xi_{4\,I}$	$+ \xi_{4\,II}$

Fig. 10 .- Numerical and graphical representation of the regression polynomes of the relative dry weight for both experiments.

A PROPOS DE L'HELIO-PHYTOTRON DE GORSEM

Pot'

C. S1RONVAL, Laboratoire *de* Physiologie Vegetale,
Gorsem, Saint-Trond, Belgique.

Je dois vous faire une confession : je n'aurais jamais cru, lorsque j'ai entendu parler pour lo premiere fois d'un phytotron, que je me trouverais un jour devant une nombreuse assemblee specialement convoquee pour en discuter des heures durant.

Cela se passait vers 1950. C'est en effet a Liege ,-il fact, je crois, le dire,- que *le premier* phytotron a ete construit en Europe. L'initiative en revient au Professeur R. BOUILLENNE, ici present, qui, rentront de Pasadena, of., it avait rendu visite au Professeur F. WENT, avait congu tout l'interet de cet appareillage. Lorsque le Professeur BOUILLENNE a enonce **le** terme de "phytotron" devant nous, ses eleves, nous l'avons regarde, nous avons ri, et nous n'avons pas compris. Nous ne savions pas de quoi i t s'agissait ... Nous avons seulement cornpris de quoi ii sragissait quand, un an plus tard, le phytotron de Liege s'est mis a fonctionner, et que le Professeur CHOUARD est venu Pinaugurer.

On peut faire beaucoup de chores avec un phytotron. Pour ma part, je ne suis pas ecologiste. A peine suis-je physiologiste : rrx:m laboratoire s'interesse au contenu des plantes et a ses variations en rapport avec le developpement et le milieu.

Lorsqu'un biochirniste experimentait autrefois sur les chloroplastes, comment procedait-il generalement ? II allait au marche. II s'y procurait un demi-kilo d'epinards. Avec ce demi-kilo, it faisait des mesures, par exemple en utilisant les methodes de Warburg. Parfois ('experience donnait tin resultat ; parfois elle se deroulait autrement et donnait tin autre resultat, parce que les epinards du marche etaient, ce jour-la, differents de ceux du jour precedent. *Eux* aussi, venaient du marche, mais c'etait d'autres epinards

Le phytotron seul nous permet de reproduire vraiment, d'une maniere striate et contralee, on organe (tel un chloroplaste) a volonte identique a lui-meme, -et par consequent, d'utiliser choque fois, dons des experiences successives, le meme materiel vegetal. C'est un avantage indeniable. II en est un second : c'est qu'a ('aide d'un phytotron, it est possible de comparer des materiaux differents, de les produire et de les reproduire. J'ai eu l'honneur de montrer, au recent Congres de Photobiologie d'Oxford, qu'un chloroplaste d'epinard obtenu en 8 heures de jour, nest pas identique a un chloroplaste de la mime variete, obtenu dans les mernes conditions, mais en 16 heures de jour., La structure est differente ; le contenu est different ; le fonctionnement est different.

A Gorsem, nous etudions speciolement les chloroolastes. Notre phytotron sert a fournir tin materiel defini (ou plusieurs) pour cette etude. II est congu comme suit : nous disposons d'une cave assez grande dans laquelle une serie de 8 chambres conditionnees separees sont instal lees. Dans chacune de ces chambres la temperature est regloble a un degre pres, entre dix et trente degres centigrades. L'intensite lumineuse, la duree des jours et is qualite de la lumiere sont egalement reglables. On petit contreder l'humidite de l'air. Lc: cave communique avec le laboratoire de biochimie par tin monte-charge, et les plantes (ou leurs organes), une fois prelevees,peuvent etre immediatement soumises a ('analyse physiologique et chimique. II me parait qu'il s'agit la dune disposilion essentielle, sur iaquelle ii foul ottirer Pottention : II doit etre possible de prelever le materiel au deport des chambres conditionnees et de Vanalyser immediatement. Nous avons prevu 22 proximite *du* phytotron one chambre froide dans loquelle le materiel vegetal peut etre traire 6 baste temperature et dans les plus brels deiais.

Notre ensemble permet donc d'obord de faire croitre des vegetaux dons des conditions determinees et connues et citetudier ensuite les caracteres biochimiques et physiologiques des chloroplastes obtenus. En particulier, l'octivite phr.2tosynthetique globale des feuilles est mesuree dons une chambre speciale (voisine des chambres conditionnees) dons loquelle le milieu est contrelable, et ou centre de loquelle se trouve 4.me forte source lumineuse (une lamps OSRAM au xenon XBF 6000). Nous appelons cette chombre "1161 iotron". On dispose des plantes provenant du phytotron autour de lo source iumineuse de l'heliotron. L'enregistrernent de la photosynthese *est* auiomatique. El se fait a !'aide d'un oppareil de detection IR du CO_2 du type URAS. A la longue, nous esperons mettre en evidence des relations entre les conditions (au tens le plus large) dans iesquelles les plantes sont cultivees, le type et le contenu de leurs chioropiostes, et les caracteres de leur oct [vire photasynrhetique globale, voire les caracteres de l *eur* developpement et de leur croissonce en general.

Ce travail est octuellement en tours. -le ne vois pas vous dire quel en est le resultat ; cela m'ecorterait du but de cette seance.

Nous construisons nous-memes not chcrmbres. La figure 1 monlme *!'une* d'entre elles. On y distingue les lompes dons lo pantie superievre. Le renouvellement de fair se fait par un circuit portant du has vers le *haut* de la chambre. Le prix dune chambre ne deposse pas septante mille francs beiges (environ 500 !lyres sterling). La figure 2 montre 1'141 iotron. La lompe centrale au xenon est al Iumee. On petit voir **la** disposition des plantes. Sur cheque plante, une feuille determinee est choisie pour la mesure de *la* photosynthese. La photosynthese de 12 feuilles distinctes peut etre enregistree dans l'appareil URAS. Deux enregistreurs spares notent les mesures svccessivernent (figure 3).

Fig. 1 .- L'une des chambres conditionnées de l'hélio-phytotron de Gorsem. On voit, par la porte entre-ouverte, les tables, à hauteur variable, permettant de rapprocher plus ou moins les plantes des lampes situées au plafond.

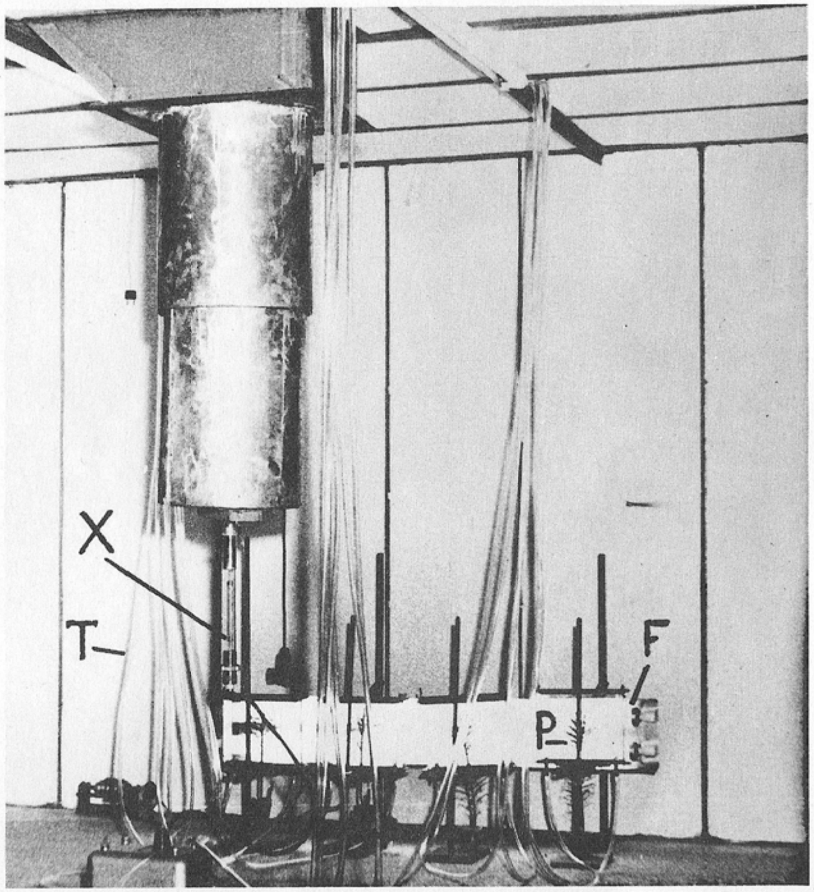


Fig. 2 .- Intérieur de l'héliotron. La lampe Xenon (X) n'est pas en service au moment de la photographie. Les plantes en expériences (P) sont soumises, à ce moment, à l'éclairage des tubes fluorescents (F). On voit les tuyauteries (T) de circulation de l'air de mesure.

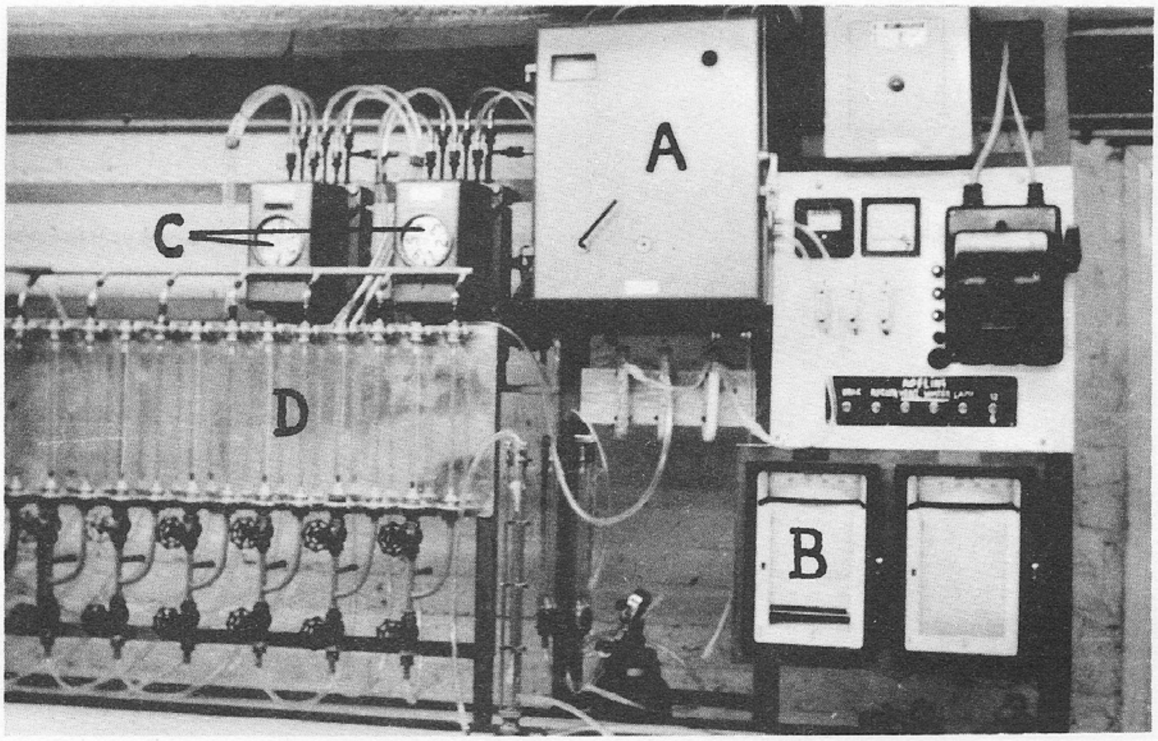


Fig. 3 .- Les appareils de mesures attenant à l'héliotron : A = appareil URAS ; B = enregistreurs ; C = commutateurs automatiques ; D = rotamètres.

MEASUREMENT OF SPECTRAL ENERGY DISTRIBUTION OF ARTIFICIAL ILLUMINATION IN PHYTOTRON AND GROWTH CABINET

by
Yuichiro NISHIZAKI and Yoshiharu ODA
Institute for Agricultural Research, Tobyku University, Sendai, Japan.

In recent years phytotrons and growth cabinets with artificial illumination have been much used for plant experimental work. We have to use several kinds of artificial light in order to get normal growth of higher plants. The spectral distribution of each light source was already known, but it is very difficult to measure precisely the spectral energy distribution of complicated system as a whole. However, the knowledge of spectral energy distribution, besides intersity, of the light is indispensable to the analysis of the effect of light on the plant growth.

In this report the results are given of measurements of the spectral energy distribution in our phytotron and growth cabinet by the photographic-plate method.

For the purpose of estimating the spectral distribution of the light by which plants were actually illuminated, we bad to measure the ensemble of the direct and the indirect (reflected) lights, which was achieved by the use of a neutral light-scattering element, a magnesium oxide-coated plate. The light reflected by this plate was introduced to a spectrograph and photographs of spectra were obtained. By comparing the concentration of the spectrophotographs with that of a "standard" lamp, the spectra] distribution of the incident light could be estimated. The experimental device used is shown in Fig. 1 and 2.

The light reflected by the magnesium oxide-coated plate was reflected by a concave mirror with the radius of curvature of 30 cm to focus the image of the plate at the slit of the spectrograph. A projection lamp (200 W, 100 V;) was used as a "standard" lamp and was set so as to illuminate the magnesium oxide plate at an angle of 45°. For longer exposures, a hand shutter of the spectrograph was used, and if necessary, the foal plane shutter of a camera was used for shorter exposures, set in front of the slit. To take the spectrophotographs, Process Panchromatic Fuji-plates were used. They were developed under the constant condition. Densitometric analyses of the spectral photographs were done with a recording microphotometer.

The arrangement of illumination lamps in our phytotron and growth cabinet are diagrarnatically shown in Fig. 3 and 4. The Floor space of the phytotron and the growth cabinet are around 11.2 m2 and 3.75 m2, respectively. The light sources attached were as follows :

Phytotron	Light sources	Number
	- Reflector (incandescent) lamps (200 W, 100V)	20
	- Super-high-pressure mercury-vapour lamps (HL-400W)	3
	- Fluorescent high-pressure mercury-vapour lamps (NFL - 400 W.)	9
	- Fluorescent lamps (FL-40 W-DL, cool white)	59
	- Slim-lined lamps (FSL-48 T 8 W, white)	108
	- SLim- lined lamps(FSL - 96 T 12 W, white)	24

Growth cabinet

Light sources	Number
- Incandescent lamps (200 W, 220 V.)	3
- Fluorescent high-pressure mercury-vapour lamps (HFL-400 W)	4
- Slim-lined lamps (FSL - 64 T - 8 D - daylight)	36

The measurement of the spectral energy distribution was made by putting the magnesium oxide-coated plate at the center of the turntable (phytotron) or on the table 75 cm in height (growth cabinet).

About 30 minutes after all the lamps in the phytotron or growth cabinet had been switched on, spectrophotographs of the light completely scattered at the magnesium oxide-coated plate were taken with varied irtervals of exposure time. After switching them off, the spectrophotographs of the "standard" lamp were also taken on the same photographic plate in the similar way. The interval of the exposure time was changed so as **to get** enough density for a direct comparison of both series of photographic record on the some plate. Examples of the spectrophotographs are shown in Fig. 5.

It is important to compare one series with the other on the same plate in order to avoid errors the developing procedures are likely to make. The photographs thus obtained were subjected to the densitometric analysis with a recording microphotometer.

Then we must compute the intensity of the light at each wavelength according to the formula

$$r = \frac{E_1}{E_2} \frac{T_1}{t_1} \Big/ \frac{T_2}{t_2} = R \frac{T_1 t_2}{t_1 T_2} \qquad (1)$$

T2 T 1 t -R TT

$$R = \frac{E_1}{E_2} \qquad (2)$$

In this formula, r is the unknown ratio of the incident energies at wavelengths A,„ and A,. R is the known ratio of the energy at A,, and A,of the "standard" lamp light. t_i and T_1 are the intervals of the exposure time for the room light and the "standard" lamp, respectively, to obtain the some density on the plate at lambda1, t_2 and T_2 ore also the intervals of the exposure time for both the light at lambda2. The ratio, r, of the incident light was determined at various wavelengths, lambda1 , being fixed. Thus we can measure the spectral energy distribution curve of the incident lights.

Spectral energy distribution curve thus obtained in the phytotron is shown in Fig. 6. The dotted line shows the spectral distribution of the "standard" lamp. We can see clearly ten bright lines of the mercury discharge and relatively large energies of longer portion of the spectrum. The latter is due to more reflector lamps fixed in the phytotron.

The results in the growth cabinet is shown in Fig. 7. We can also see clear ten bright lines of mercury discharge. But we can find that the longer portion of the spectrum is less in the growth cabinet than in the phytotron, as the number of the incandescent lamps is smaller in this case.

The possible causes of errors involved in the present method are :

a) The deviation from the reciprocity law in the photographic plate.

b) The photographs of the spectra were taken in exposures shorter than 1 second to obtain appropriate densities of the intense emission lines from the mercury discharge. The intervals of exposure For the spectra of the "standard" lamp necessary for matching the densities of the emission lines usually ranged from four to ejght minutes. Thus, the accuracy of the focal plane shutter makes a limiting factor in the determination of r in the formula (1). Therefore, in the curves of the energy distribution, we can not compare exactly the energies of the line spectra with that of the continuous spectra.

In addition , some examples of growth pattern of test plants are shown in Fig. Band 9 which indicate the different patterns cultured in the phytotron and in the growth cabinet. They may be due to the difference in the spectral energy distributions.

Fig. 8 shows the growth pattern of *Lemna perpusilla,* a typical short day plant, cultured for nine clays at 26°C under the continuous illumination of 7.000 lux. A is under the fluorescent lamp only ; B in the growth cabinet ; and C in the phytotron. The plant growth is most vigorous in the phytotron in which many incandescent lamps are arranged. Fig. 9 shows a feature of the growth pattern of *Lemna gibba* , a typical long day plant, under the same cultural condition as *L. perpusilla.* In this case, the incandescent lamps in the phytotron rather inhibited the growth of the plant.

In conclusion, it is very important to measure the spectral energy distribution of the artificial light, because the composition of the lights has a great influence of the growth pattern and.photomorphogenesis of plants. Thus, in future, such an approach will bring with it one of the most precious contributions to phytotronics.

Reference.-

NISHIZAKI, Y. and ODA, Y. (1963).- *Sci. Rep. Res. Inst.* Tohoku Univ., D-14, 1-14.

⁂

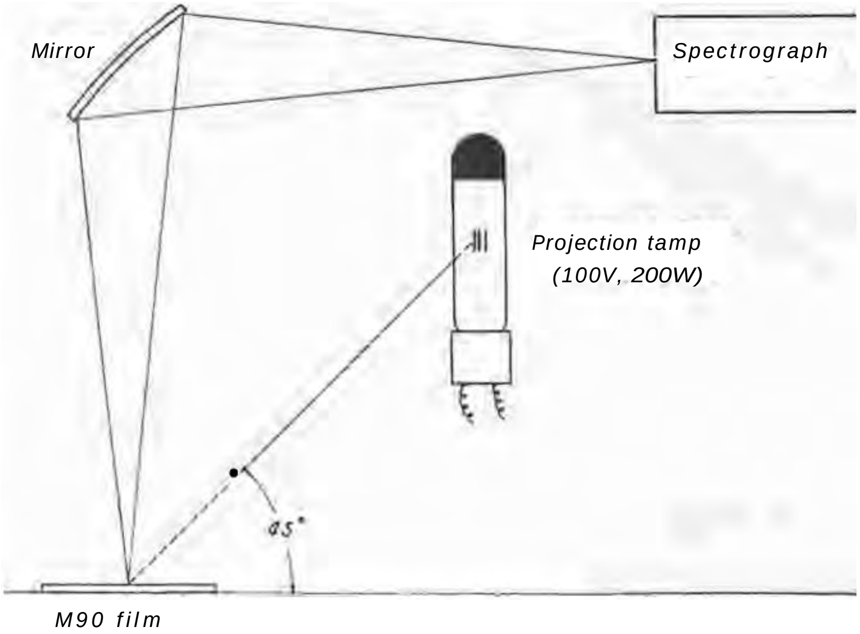


Fig. 1 .- Diagram of measuring apparatus.

Fig. 2 .- Measuring apparatus. White circular plate : Mg0 film.

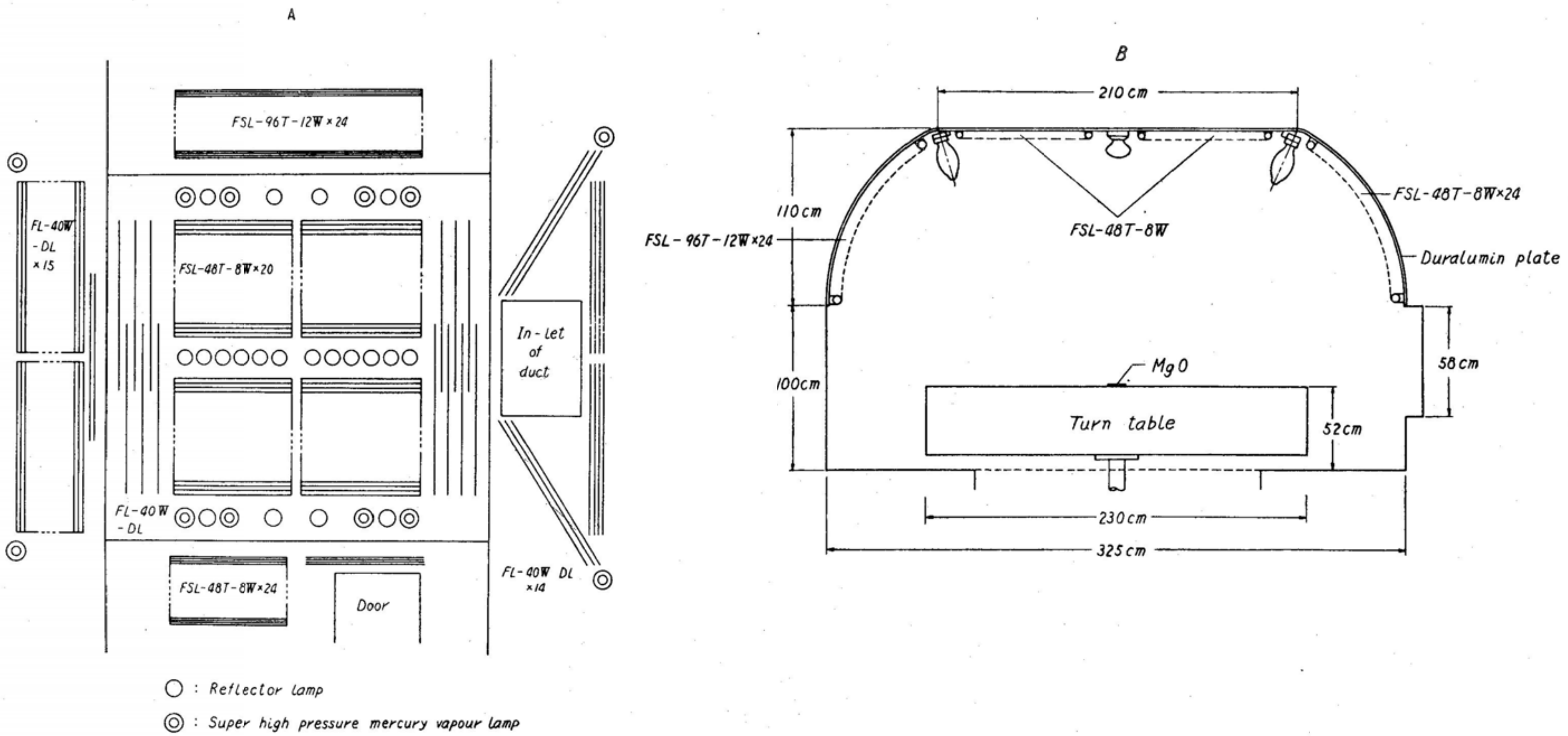


Fig. 3 .- Arrangement of illumination lamps in Phytotron. A : development ; B : end view.

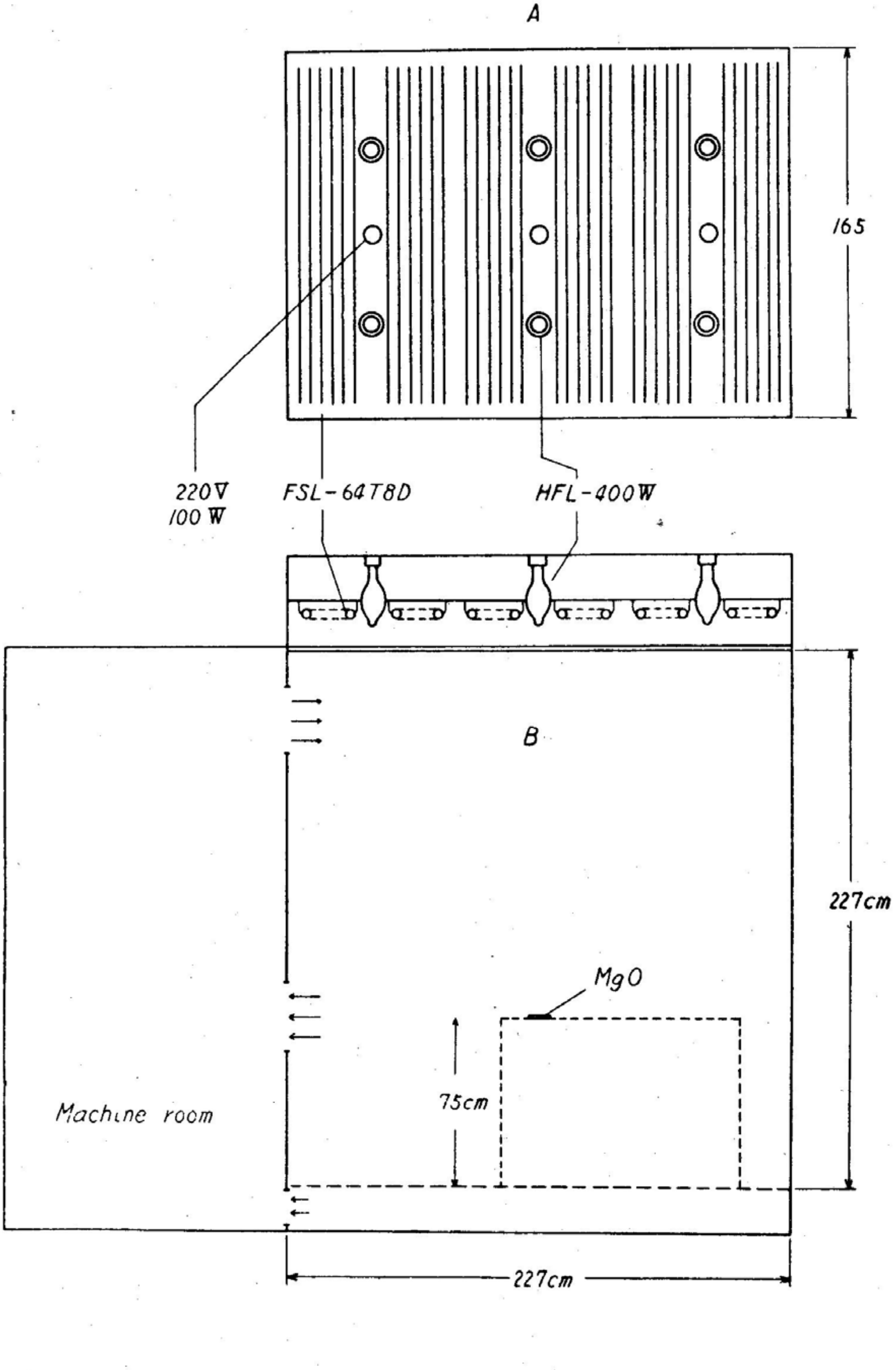
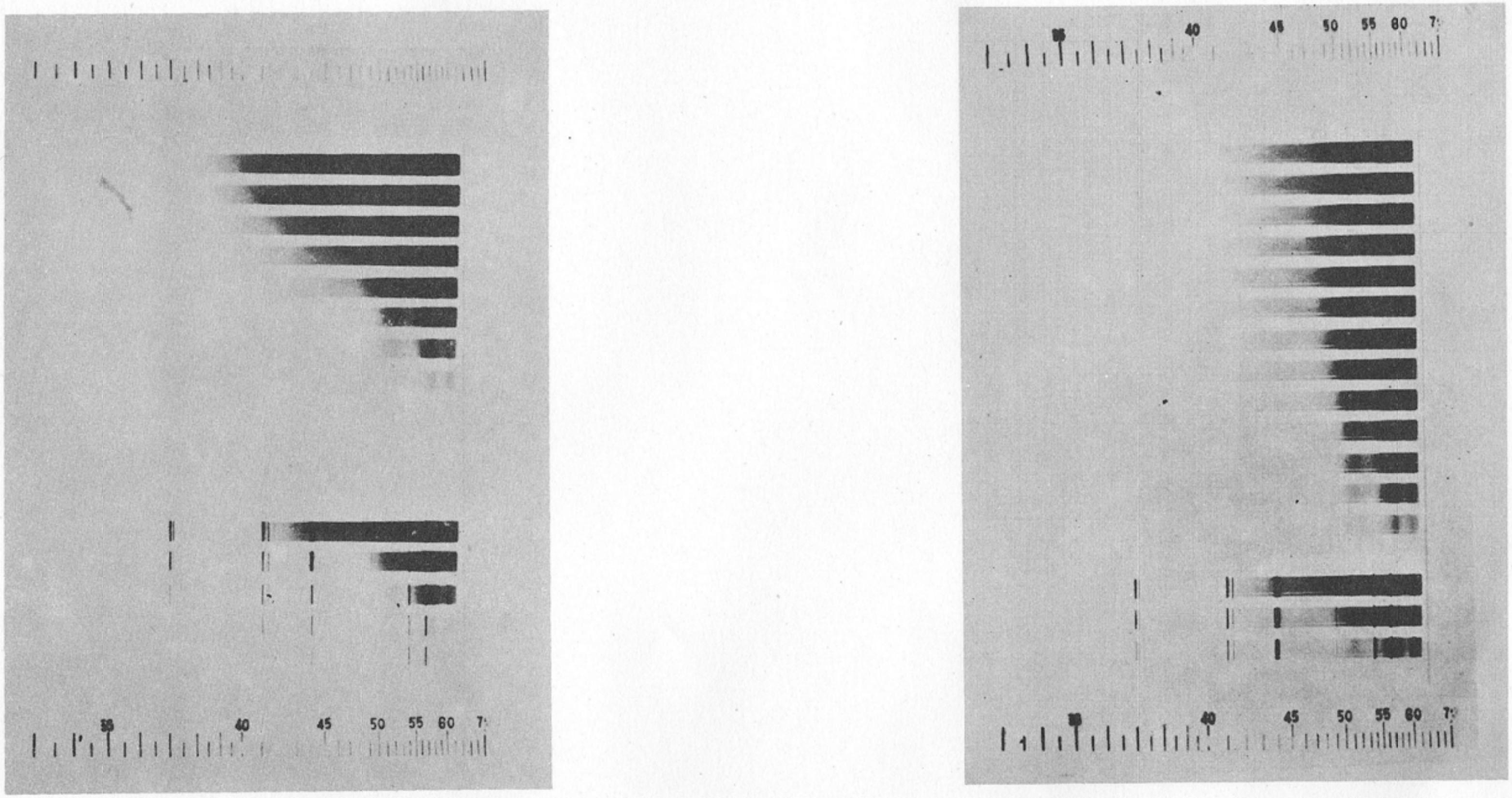


Fig. 4 .- Arrangement of illumination lamps in growth cabinet. A : plan figure ; B : end view.



Phytotron. From upper ; "standard" lamp, exposure times : 60, 40, 20, 10, 5, 2, 1 min., 20, 10, 5, 2 sec. ; experimental lamps, 2 min., 30, 10, 1, 1/25 sec.

Growth cabinet. From upper ; "standard" lamp, exposure times : 22, 20, 18, 16, 14, 12, 10, 8, 6, 4, 3, 2, 1 min. ; experimental lamps, 4, 2, 1 min.

Fig. 5 .- Photographs of spectra.

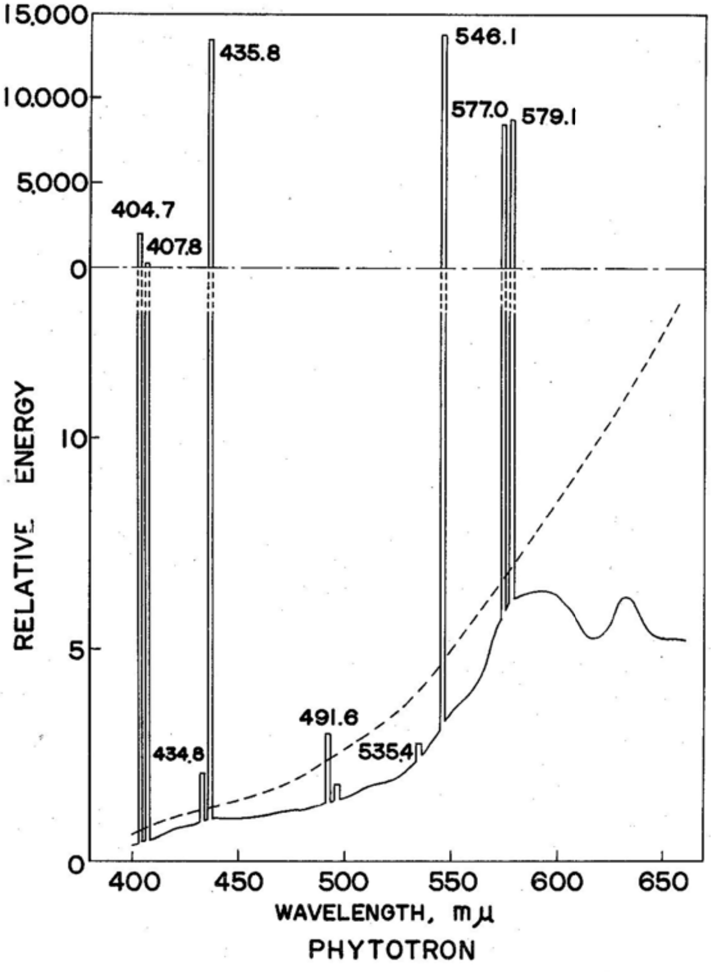


Fig. 6.- Spectral energy distribution curve in Phytotron.

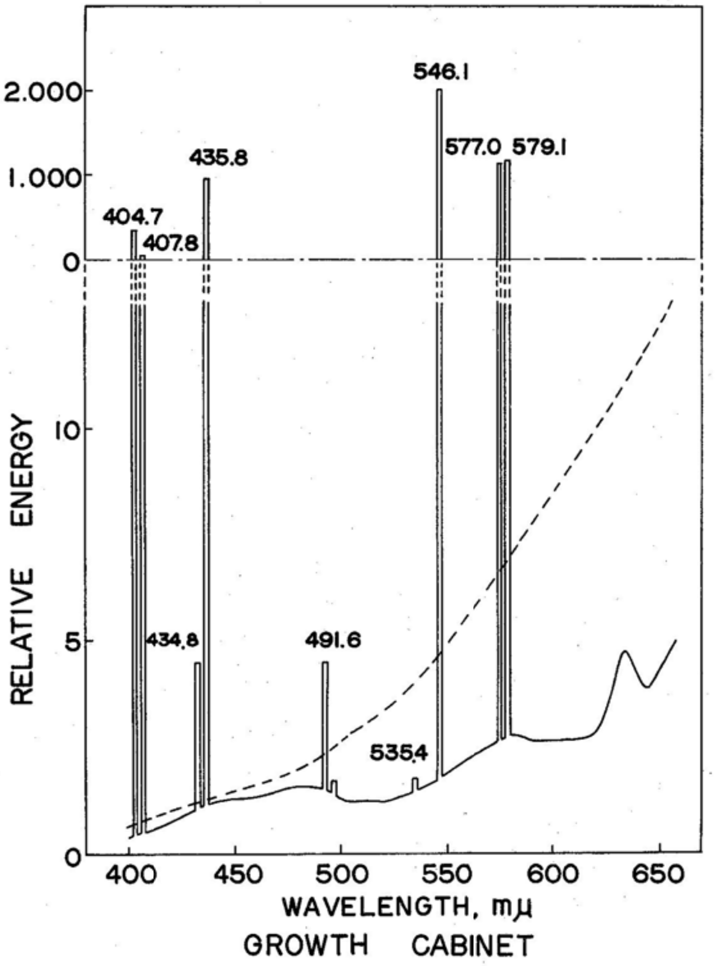


Fig. 7 .- Spectral energy distribution curve in growth cabinet.

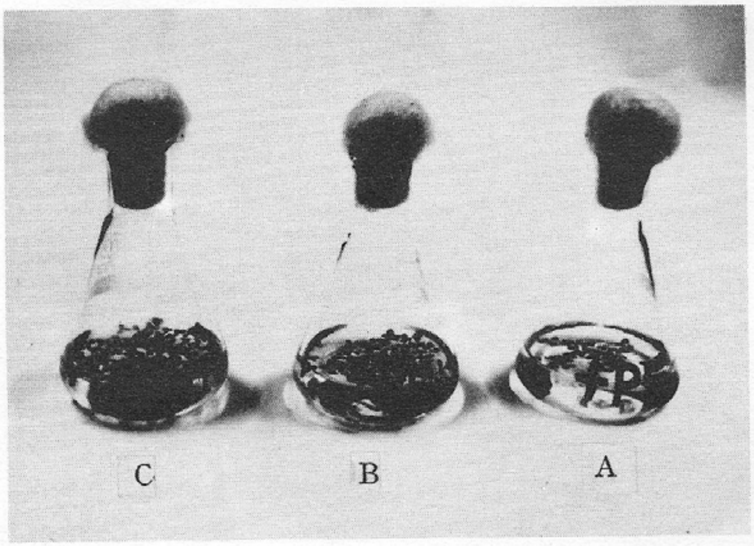


Fig. 8 .- Lemna Perpusilla (see text).

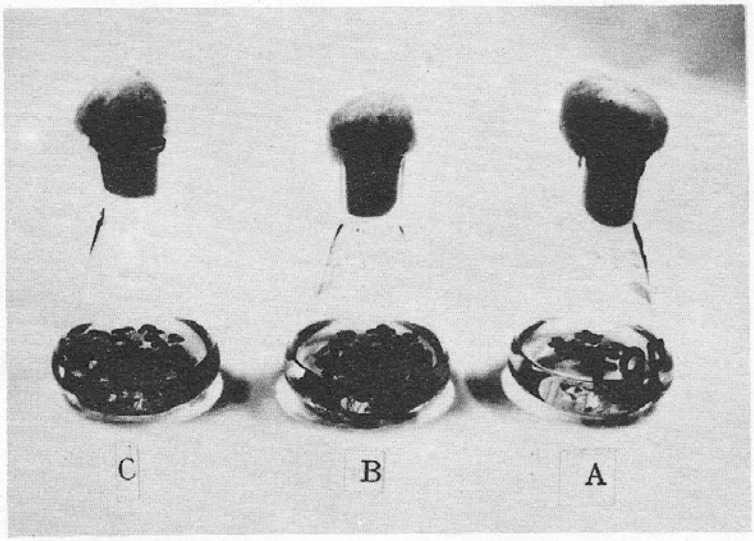


Fig. 9 .- Lemna gibba (see text).

THE PHYTOTRON DESIGN

by

Dr L. T . EVANS - CS1RO - CANBERRA

At one stage this morning it looked as though there would be time for only one sentence in which to summarize this morning's proceedings, and that sentence would have had to be "That different phytotrons differ in different ways". This summary could also apply to this afternoon's proceedings, which have amply underlined Dr Koller's remarks in opening this Symposium discussion. Faced by this tremendous diversity of hardware, Dr Koller suggested that it would be desirable for us to develop, as far as possible, a common engineering approach to the problems of phytotron design.

I believe that it is much too early to attempt this because we have as yet by no means exhausted the ingenuity of our engineers, and each new phytotron adds new ideas to the design pool. Moreover, the design of each phytotron, and the engineering approach to it, will depend on the experimental requirements of the population it is to serve, and on the climate in which it is to be built. Also, if only to assuage the micrometeorologists, we will have to introduce further complexities into the controlled environment conditions which we provide in phytotrons. For example, our present aim is generally to grow plants in spatially uniform conditions. Such conditions give us a lot of physiologically useful information, but in the field plants may be subjected to marked gradients between their various ports, and these gradients may have important physiological consequences. A first step in providing such gradients is to provide different root and shoot temperatures, but we will eventually have to provide far more subtle gradients than these, and this will probably require an entirely different approach on the part of our engineers. Instead of using the conventional air conditioning techniques of moving a lot of air at set temperatures around the plants, we may have to rely on spatially separated sources and sinks for radiation.

Thus, I think we must tolerate, indeed welcome, the present diversity of engineering approaches in phytotron design. I would like to emphasize, however, for those who envisage developing new phytotron facilities, that the cost of engineering development itself can become a significant part of the total expenditure, so much so that one should perhaps not undertake it without very good reason. Also, since phytotrons are so costly to build and develop, and therefore must serve a large and often changing population of scientists over a period of years, it may not be advisable to design them too closely for one particular kind of work, but rather to provide units of sufficient flexibility to serve many experimental purposes. So now I have come full circle and end up by supporting Dr Koller's plea to some extent on the grounds of the high development costs and of the advantages of general purpose units.

In this context, then, we need more discussion of the relative advantages of the various approaches to the basic design features of a phytotron. The most bas icof these are :

(1) Whether to have fewer, larger rooms on set conditions and shared by many workers, or more small autonomous cabinets ;

(2)Which components of climate are the most important to control, and to what extent should one use natural or artificiol light ?

(3) With what accuracy should the various factors be controlled ?

Cabinets versus Rooms.

The protagonists of the room design, as employed in the original Californian phytotron and in most of those built subsequently, have advanced many arguments in favour of a room-rype phytotron. Among these ore that it is more convenient to administer, that users con manipulate or measure their plants with little loss of condition control, and that it is more suitable for work with large plants. Some advantages of the cabinet-type phytotron, which we have built in Canberra are :

(1) The cabinets may **be** set for any conditions whithin their operating range, whereas for moms a few standard conditions must be selected ;

(ii) More rigorous control of conditions is possible than where many workers have access to each room, and greater precision of control is obtainable in the smaller units ;

(iii) Replication of conditions as well a within conditions is possible, and is often wanted ;
(iv) Elimination of the daily movement of plants reduces labour requirements and errors in conditions setting, and obviates damage to plants and loss of control at moving time ;

(v) Ample testing of the basic units can be carried out before the whole installation is built ;
(vi) The cabinet can be factory-built and checked under rigid production control, resulting in a higher standard of workmanship than is possible for on-site construction;

(vii) Isolation of sections for work with soils or on plant diseases under non-sterile conditions can be readily arranged;

(viii) Future expansion and modification of the installation is easier, and it can be built in stages.

We felt ***these*** were very real advantages, and we would therefore agree with the analysis made by Dr NITSCH this morning. However, I believe romm design could be improved a lot more and the development of prefabricated units could make **them a more** attractive possibility. In fact, we have both room: and cabinets in the Canberra phytotron and such a mixture is probably the best compromise.

<u>The Climatic</u> Components <u>to be Controlled.</u>-

These will, of course, vary depending on the purposes of the phytotron. However, it might be worthwhile to indicate that in the first two years of operation of the Canberra phytotron, which serves a fairly large group of biologists from about a dozen disciplines, the order of requirement for control has been os follows : -temperature> photoperiode > light intensity> humidity > windspeed, atmospheric composition, etc... I might add that we hove been rather surprised at how many people have requested independent control of top and root temperatures.

<u>Level of Environment Control</u> . -

The biologists concerned with phytotron design probably tend to specify a higher degree of control than they really **require, more** in hope than in expectation. The engineers then prove that they can attain these levels, and we end up with something for more elaborate and costly than is often needed. In Canberra, we have three general levels of environment control. Two-fifths of our space is at the lowest level of control in green. houses with day temperature controlled between 15°C and 36°C -I- 1/2°C, with doylengths of either 8 or 16 hours, under natural light. About two-fifths of our space is at the middle level of control, in cabinets which provide closer temperature control over a much wider range of operation, at any photoperiod, but still subject to fluctuations in natural light intensity. The rest of our space is at the highest level of control with very close control of temperature, phatoperiod, light intensity and humidity over a wide range of operation. initially, we thought we had provided too high a proportion of space with the lowest level of control, but this has proved to be very popular and is fully used for prelimirary experiments, and for less critical stages of more elaborate experiments. Such a mixture of levels of control is much more economical than providing full control at the highest level throughout the phytotron. To emphosize this point, the approximate relative cost per square metre for our lowest, middle, and highest level of control are as 1 7 : 10 for the initial capital cost, and as 1 : 1 : 2 for running costs.

For comparison with the figures given by Dr NITSCH for the Paris phytotron the actual cost of building and equipping the Canberra phytotron was about % 5.000 per square metre of controlled growing space. Our actual running costs for this last year have been about $ 33 per square metre per month, 2/5 the of this being for salaries and the remainder for maintenance of all kinds.

A final word about phytotronics. This morning, with his customary Gallic persuasiveness, Prof .CHPUARD made a case For phytotronics and for an association of phytotronists. I must confess I feel a little uncomfortable with this label. A phytotron is an extremely useful tool, lust as is a Spina() Centrifuge of a thermostatically controlled waterbath, but 1 do not think it has a separate science of its own. Scratch a phytotronist and you find a plant physiologist or on ecologist ar a geneticist, and the full potential of phytotrons will be realized only when all these and many other scientists have learnt to exploit controlled environment facilities for their own purposes. By calling ourselves phytotronists we may give the impression that we are a separate breed, and may prevent the fullest use of phytotron facilities.

⁂

SOME COMPARISONS BETWEEN RADIATION IN GROWTH ROOMS AND RADIATION UNDER NATURAL CONDITIONS

by

Dr P. GAASTRA, Laboratorium voor Plantenphysiologish Onderzoek van de
Landbouwhogeschool Wageningen - Nederland -

I - INTRODUCTION

Many lamp types are available for installation in growth rooms. Apart from economic and technical factors -which are not discussed- the choice is determined by the types of experiments to be carried out in the rooms. For investigations of the relation between spectral composition and developmental processes, several lamp types, usually in combination with optical filters, should be available. This special case also will not be considered.

Many experiments require the same spectral quality in several growth rooms. Such rooms are used for investigations of the effects of daylength and irradiance upon various physiological processes, and for studies of the effects of other environmental factors (air, humidity, temperature, soil factors etc...) or chemical treatments, under constant radiation conditions. Of course, interactions between radiation and other factors can also be the object of study.

A special case is the use of one spectral quality for investigations, in which it is tried to obtain more information about the interaction of physiological processes under natural conditions. It is not necessary -and mostly impossible- to duplicate for example the diurnal course of outside conditions, but the equipment should preferably be such that the potential rates of the relevant processes are at least comparable with those to be expected under natural conditions. If this is not possible, information is required about the approximate difference between both. This paper deals with the evaluation of some of these featu;es for radiation active in photosynthesis and photophormative processes.

The possibilities of various lamp types could be compared by surveying the published performance of growth rooms, used at different laboratories. This is not done, because these data are badly comparable, which is due to differences in size of the growth rooms, density of lamp packing, optical properties of lamp and growth rooms, etc...

The basic data used in this paper are the lamp characteristics given by the manufacturers. Furthermore, certain assumptions are made about the number of lamps installed, and about the radiation losses in lamp and growth rooms. The disadvantage of this procedure is that the absolute values are valid only for the specified conditions. This is accepted in favour of the increased comparability of physiological effects obtained with different lamp types.

The next paragraph deals with the conversion of the manufacturers' data into physiologically useful units. In paragraph 3, the photosynthetically active radiation in growth rooms is compared with sun + sky radiation at Wageningen, and in paragraph 4 similar comparisons are made for radiation active in photophormative processes.

II.- CONVERSION OF PHOTOMETRIC UNITS INTO PHYSIOLOGICALLY USEFUL UNITS

Manufacturers usually give the following lamp specifications :

- wattage : W watt / lamp (1)
- luminous flux : L lumen/ lamp (2)
- spectral energy distribution : E_λ arbitrary units of energy flux (3)

The total output of the lamps is given in photometric units, which are based upon the spectral dependence of human vision. The spectral sensitivity of the human eye deviates from the spectral sensitivity of photochemical processes in plants, so that for work with plants the luminous flux should preferably be converted into the energy flux, emitted by the lamps.

Conversion of photometric units into energy units is described earlier (GAASTRA, 1959), so that a brief outline of the procedure is sufficient. The luminosity curve gives the spectral sensitivity of the human eye in relative units :

$$V_\lambda \text{ lumen / energy flux } (0 \leqslant V_\lambda \leqslant 1) \qquad (4)$$

The maximum sensitivity is obtained at 555 nm ($V_{555} = 1,0$), and the absolute value is then given by the mechanical equivalent of light :

$$M_{555} = 650 \text{ lumen watt}^{-1} \qquad (5)$$

The absolute value of M_λ at any wavelength is

$$M_\lambda = 650\, V_\lambda \text{ lumen watt}^{-1} \qquad (6)$$

Since 1 watt = 10^7 erg sec^{-1}, Eq. 6 can be written as

$$1 \text{ erg sec}^{-1} = 650 \times 10^{-7}\, V_\lambda \text{ lumen} \qquad (7)$$

Eq. 3 gives the spectral energy distribution in relative units, and absolute units are obtained by multiplication with an unknown factor y :

$$E'_\lambda = y\, E_\lambda \text{ erg sec}^{-1} \text{ nm}^{-1} \qquad (8)$$

From Eqs. 7 and 8 follows that

$$y\, E_\lambda \text{ erg sec}^{-1} = 650 \times 10^{-7}\, y\, E_\lambda\, V_\lambda \text{ lumen} \qquad (9)$$

and the energy flux between wavelength limits w_1 and w_2 nm then is

$$y \int_{W_2}^{W_1} E_\lambda\, d_\lambda \text{ erg sec}^{-1} = 650 \times 10^{-7}\, y \int E_\lambda\, V_\lambda\, d_\lambda \text{ lumen} \qquad (10)$$

These integrals could not be calculated, but their approximate values were obtained by taking representative values of E_λ and V_λ for wavelengths intervals of 10 nm, and by adding these values over the wavelength region $w_1 - w_2$. In this way, the ratio between the photosynthetically active energy flux (w_1 = 400 nm, w_2 = 700 nm) and luminous flux was calculated :

$$E_{400-700}/L = 1.54 \times 10^4 \sum_{400}^{700} E_\lambda \,/\, \Sigma\, E_\lambda\, V_\lambda \text{ erg sec}^{-1} \text{ lumen}^{-1} \quad (11).$$

Since 1 lux = 1 lumen m^{-2}, for flux densities the ratio becomes

$$E_{400-700}/L = 1.54 \sum_{400}^{700} E_{\lambda} / \sum E_{\lambda} \quad V_{\lambda} \quad \text{erg cm}^{-2}\ \text{sec}^{-1}\ \text{lux}^{-1} \qquad (12)$$

The photosynthetically active radiation is represented by the energy flux density between 400 and 700 nm. However, photosynthesis is more directly related with the absorbed flux of Einsteins in this region. This flux depends upon the number of Einsteins per erg and upon the fractional absorption coefficient of the leaves. Both are a function of wavelength. It can be derived (GAASTRA, 1959) that

$$1 \text{ erg} = 8.37 \times 10^{-16} \lambda \ \text{Einstein} \qquad (13)$$

in which λ is expressed in nm. For leaves with fractional absorption coefficient a_{λ} $(0 \leqslant a_{\lambda} \leqslant 1)$, the ratio between energy incident upon the leaf (E_{λ}) and absorbed Einsteins ($Q_{a,\lambda}$) was calculated according to

$$(Q_a/E)_{400-700} = 8.37 \times 10^{-16} \sum_{400}^{700} E_{\lambda} \ a_{\lambda} \lambda \ / \ E_{400}^{700} \ E_{\lambda}$$

$$\text{absorbable Einstein erg}^{-1} \qquad (14)$$

in which a_{λ} is the absorption coefficient for leaves with "normal" absorption characterictics (taken from MOSS and LOOMIS, 1952).

Table 1, column 2, shows that the ratio between photometric and energy units ($E_{400-700}/L$) varies largely with lamp type, which demonstrates that photometric units are unsuitable for the characterisation of photosynthetically active radiation. On the other hand, the ratio between absorbable Einsteins and incident energy ($(Q_a/E)_{400-700}$, column 3) is very constant, so that for leaves with average absorption characteristics the photosynthetically active radiation is well represented by the energy flux density at the leaf surface.

The radiation fluxes emitted by 40 W -fluorescent lamps of different types are compared in Fig. 1. The variation with lamp type of the luminous flux (L) deviates appreciably from the variations observed for the fluxes of energy (E) or absorbable Einsteins (Q_a), while the variations of E and Q_a are very similar. This demonstrates that comparisons of total luminous fluxes are an unsuitable basis for the evaluation of the photosynthetic possibilities of different types of fluorescent lamps.

For the calculations in the next paragraph, the relation between photosynthetically active radiation ($E_{400-700}$) and electrical energy consumed by the lamps, should be known. This efficiency of energy conversion is obtained as follows : The energy output per lamp ($E_{400-700}$) is derived from the luminous flux (L,eq.2) and the ratio of energy and photometric units ($E_{400-700}/L$), eq. 11, and column 2, table 1) :

$$E_{400-700} = L \ E_{400-700}/L \ \text{erg sec}^{-1} \qquad (15)$$

The electrical energy consumed par lamp is

$$W \text{ watt} = W \times 10^{-7} \ \text{erg sec}^{-1} \qquad (16)$$

The efficiency of energy conversion is derived from eqs. 15 and 16 :

$$100 \ E_{400-700} / (W \ 10^{7}) \ \% \qquad (17)$$

Efficiency values (tables 1 and 2, colums 4) vary largely between fluorescent lamps, and the values of these lamps are higher than those for mercury vapour lamps, while Xenon lamps are the poorest energy converters. For fluorescent lamps, the efficiency decreases with increasing wattage. The efficiency of high pressure mercury vapour lamps with reflector is lower than that for similar lamps without reflector, but the difference is partly compensated by a better downward reflection of the emitted radiation.

III.- A COMPARISON BETWEEN THE FLUX DENSITIES OF PHOTOSYNTHETICALLY ACTIVE ENERGY UNDER NATURAL CONDITIONS AND THOSE OBTAINED IN GROWTH ROOMS WITH DIFFERENT LAMP TYPES.-

Calculation of the energy flux densities ingrowth rooms.-

For these calculations it is assumed that the lamps are mounted in a lamp room above the growth room, and that the rooms are separated by one or two sheets of transparent material,

Sets of fluorescent lamps can be mounted in several ways, and the effects of various possibilities upon radiation intensity and regularity of radiation distribution in the growth rooms are given by CARPENTER et al. (1960, 1965), and PESCOD *et* al, (1963). Here is assumed that the lamps are densily mounted in one horizontal plane of appreciable size (several square meters). The distance between the lamps is taken as 1 cm. From the size and wattage of the lamps, follows the number of watts (W'watts m^{-2}) installed for closely pocked fluorescent lamps (column 2, table 2). The same column also shows the values of W' chosen for mercury vapour lamps and Xenon lamps. This choice is somewhat arbitrary, but application of denser packing seems unreasonable. Since these lamps combine a small size with a high wattage, approximate values of radiation intensities for more widely spaced lamps can be obtained by proportional reduction of the value calculated for the stated density of packing.

The total energy flux of photosynthetically active radiation emitted per unit area of the lamp assembly, is obtained by multiplication of W' with the conversion efficiency (column 4, table 2). The resulting values are listed in table 2, column 3, For fluorescent lamps, only type TL-33 (white) is considered. The efficiency of this lamp decreases with increasing wattage, but the effect is largely compensated by the larger number of watts which can be installed per unit area of the lamp assembly.

The energy flux reaching the plants in the growth room is, of course, only a fraction of the total flux emitted by the lamps. The difference is a function of the operating conditions of the lamps (mains voltage and frequency, lamp temperature, age of the lamps), of radiation losses in the lamp room (absorption by the walls, reflectors, lamps), of reflection losses at the transparent ceiling of the growth room, and of the site in the growth room (decreasing fluxes towards the walls and floor, which are both a function of the cross-sectional area of the room). It was impossible to evaluate these losses separately, but actual flux measurements, 40-50 cm below assemblies of TL and HPL lamps (both with the specified density of packing), gave radiation losses between 50 and 60 %, for lamps without internal reflector. *Here,* such lamps are considered only, and the losses are assumed to be 60 % of the emitted energy (For lamps with internal reflector, the lower losses are partly counteracted by the lower emitted flux, so that the fluxes in the growth roam are close to those obtained with lamps provided with efficient external reflectors). The calculated flux densities are given in fig. 2-4, together with various aspects of global radiation *at* Wageningen. Before making comparisons, the data on natural radiation will be briefly discussed.

Freauency distribution of global radiation at Wageningen.-

Comparisons of flux densities in growth rooms with those occurring in nature, are of interest for experiments which should give information about the interaction between physiological processes under natural conditions. Such studies could, of course, be carried out in the field, but the bad reproducibility of external conditions limits the possibilities of this method. These difficulties are reduced by the use of growth rooms, if, at least, the behaviour of the plants is comparable to that expected in nature. This requires that, as far as photosynthesis is concerned, the fluxes of photosynthetically active radiation should be of similar magnitude as those occulting in nature. A minimum requirement is that the difference between experimental and natural fluxes is approximately known.

For these comparisons, frequency distributic Is of natural radiation are more important than overage values, because the distributions give information about the occurrence of extreme conditions, which are of interest for various aspects of ecological work.

DE VRIES (1955) gives frequency distributions of daily (I) and hourly (H) irradiation for each month at Wageningen. In the frequency curves -(lac. cit. fig. 3 and 7), several classes of irradiation are distinguished. They are expressed as fractions of the average values (I and H) Taking actual values fort and 1-1^{-} (loc. cit. table 2 and fig. 4), and assuming 45 % of total shortwave radiation to be between 400 and 700 nm, gives the data presented in our figs. 2-4.

Doi ILirradiation in growth rooms and under natural conditions.-

The cumulative frequency distribution for daily irradiation is given in fig. 2. In growth rooms, this value depends upon the energy flux density and daylength. Two daylengths are considered : 24 hours ([amp types between brackets) and 16 hours (lamp types without brackets). Sixteen hours irradiation with TL-40 W covers the values for the winter months (October up to February), and with continuous irradiation, this is also true for most days of March and September. If daily irradiation of the summer months has to be approached, daylengths of 16 hours are required with HPL-400 W and Xenon lamps, and with TL-120 W continuous irradiation should be applied. With TL-120 W (16 hours) and TL-80 W (24 hours), the daily values are lower than those occuring in 45 % of the days in summer.

Comparison ***of*** energy flux densities in growth rooms with overage daily irradiation.-

In Fig. 2, daily irradiation was compared with irradiation in growth rooms during arbitrarily chosen daylengths of 16 and 24 hours. A special case is presented by experiments in which the daylength should be equal to the natural daylength. The energy flux density in growth rooms then should be compared with the average daily irradiation. The latter is obtained by dividing the daily total under natural conditions by the natural daylength. The values so obtained are given in fig. 3. In the winter months the performance of the lamps is less favourable than that obtained with daylengths of 16 or 24 hours. With TL-40 W, the average doily intensity of November- to January is completely covered but this is the case for only 10-15 % of the summer days. TL-120 W covers most days from September to March, but the intensities of 45 % of the summer days are not reached. If the highest average daily intensities of the summer are of interest. HPL-400 W or Xenon lamps should be used.

Comparison of energy flux densities at noon with those obtained in growth rooms.-

In studies of the diurnal course of photosynthesis and related processes, the irradiation of the growth rooms should be comparable with those occurring under natural conditions at noon. This is especially so when large plants ore used, so that mutual shading of leaves can prevent the plants to become saturated with light at noon.

As expected, with most lamp types noon intensities are not obtained (fig. 4). TL-40 W covers 70 %of the days in November, December and January, and only 10 %of the days in summer. With TL-120 W, noon intensities of November up to February are almost completely covered, but this is the case for only 40-50 % of the days in September and March, and for 25 % of the summer days. The performance of HPL-400 W is much better, although they do not cover 55 % of the summer days. If the highest noon intensities of the summer months should be approached, Xenon lamps have to be used.

4.- SPECTRAL ENERGY DISTRIBUTION IN SOLAR RADIATION AND IN RADIATION EMITTED BY VARIOUS LAMP TYPES .-

So for, effects of radiation upon photosynthesis were considered only. Of course, radiation affects plant growth through effects upon several other photochemical processes and through effects upon the energy balance of the plants. Here only one aspect of the photophormative effects of radiation will be briefly discussed.

Photomorphogenesis and photoperiodism are affected by radiation in the red (maximal effect at about 660 nm) and infrared (maximal effect at about 739 nm) regions. The effect of red radiation can be reversed by infrared radiation and vice versa. The effect of a mixture of both qualities depends upon the ratio between both fluxes. Therefore, these ratio values obtained with various lamp types ore here compared with the values for solar radiation.

Spectral energy distributions for solar radiation and for radiation from various lamp types are plotted in fig. 5 and **6** (full-drawn curves). To improve the comparability, the amount of photosynthetically active radiation is the some For all curves. For solar radiation only one spectral energy distribution is considered (that given by MOON, 1940), because the ratio of the intensities in the red and near infrared is rather constant in natural radiation (GAASTRA, 1966).

Compared with the sun, all lamps are poor in infrared radiation. The only exception is the incandescent lamp, which explains the use of this lamp for improving the spectral quality of other lamps. In this paragraph, the spectral quality obtained with such mixtures, is compared with the spectral composition of solar radiation.

The spectral composition obtained with a mixture of lamps is obtained as follows. The number of watts installed per square meter is W_I for the incandescent lamps, and W_L for one of the other lamps. The Fluxes reaching the plants are a function of the efficiencies C_L and C_1, with which electrical energy is converted into radiant energy, and of the fraction of the emitted fluxes reaching the plants (A_L and A_1)

$$\mathrm{EL\ 400 - 700\ WLCL\ AL} \qquad \text{(18a)}$$

$$\mathrm{Ei\ 400 - 700 = WiCi\ Ai} \qquad \text{(l8b)}$$

Values for C_L ore given in table 2, and that for C_1 is about 10 %. A_L is 40 % (see paragraph 3), and the some value is accepted for A_I. ExpressinglrY$_i$ as Z % of W_t.' , gives the following fractional contribution to the total flux for each of the lamp types :

$$\text{for } L : C_L / (C_L + 0.1\ Z) \qquad \text{(19a)}$$

$$\text{for } i : 0.1\ Z / (C_L + 0.1\ Z) \qquad \text{(19b)}$$

The standardized curves for spectral energy distribution of the separate lamps (E_a ,L and ,1) ore multiplied with the Factors given in Eqs. 19a and b. The standardized spectral energy distribution for a mixture of lamps then is

$$(E\ \mathrm{lambda}\ L\ C_L + 0.1\ E\ \mathrm{lambda}\ I\ Z / (c_L + 0.1\ Z) \qquad (20)$$

The standardized values for mixtures of lamps are also given in Fig. 5 and 6.

For comparisons of the potential red and infrared effects of various lamps, the action spectra of the photophorrnative processes should be considered. Since, however, an approximate comparison of natural and artificial radiation is of interest, wavelengths with maximum effects (about 660 and 730 nm) are considered only.

Fig. 5 and 6 show that with all lamps except incandescent lamps, the intensities near 730 nm are much below those in solar radiation. Addition of incandescent lamps up to 60 % of the power installed in the other lamps, gives an appreciable increase in infrared radiation, but the value of solar radiation then is not yet reached.

More detailed information is given in table 3, where the intensities in the red and infrared are expressed in per cent of those in solar radiation. For single lamps, the intensity in the red is between 27 and 210% of that in solar radiation, and for the infrared the range is between 24 and 3 %.

Perhaps, the ratio between the intensities in the red and infrared is of more importance than the actual intensities in each region. Ratio values are given in the last Four columns of table 3. For single lamps, E_{660}/E_{730} is 5 to 20 or more times as high as for the sun. With the addition of 20 % incandescent lamps, for 6 lamp types the ratio is around 2 times that for the sun, and for the other types it is still up to 9 times as high. The last column shows that even with 60 % of the power added as incandescent lamps, the ratio for 6 combinations is still about 2 to 3 times as high as for solar radiation, and for the other lamps range between 0.9 and 1.6.

A detailed discussion of the differences between lamp types is not justified, because the spectral composition for lamps with the same type number is by no means constant. This probably is caused by the introduction of new phosphors with better properties but, unfortunately, also with different emission characteristics. Differences occur also between lamps of the same type but produced by different manufacturers. Examples of such variations are given in the data For daylight-fluorescent lamps and for HPL-lamps in table 3 and fig. 6.

In spite of these variations in spectral composition for lamps *of* the same type, the data clearly demonstrate the enormous difference in spectral quality between most lamps and solar radiation. If the quality in the near infrared should approach that of the sun, large amounts of incandescent lamps should be added to most types. Xenon lamps are a favourable exception, because their spectral energy distribution in the visible and near infrared region is very close to that of the sun.

5.- FINAL REMARK .-

The presented data should be considered purely as a comparison between natural and artificial radiation, in some physiologically important wavelength regions. The physiological consequences of differences in energy flux or spectral quality are not discussed. They will strongly depend upon other environmental factors, upon plant species, and upon the developmental stage of the plants.

REFERENCES .-

1.- CARPENTER, G.A. ; MOULSLEY, L.J., 1960 .- The artificial illumination of environmental control chambers for plant growth. J. Agric. Engng. Res., vol. 5, p. 283.

2.- CARPENTER, G.A. ; MOULSLEY, L.J.; COTTRELL, P.A. ; Summerfield R., 1965. Further aspects of the artificial illumination of plant growth chambers. J. Agric. Engng. Res., vol 10, p. 212-229

3.- GAASTRA, P., 1959.- Photosynthesis of crop plants as influenced by light, carbon dioxide, temperature, and stomatal diffusion resistance. Meded Landbouwhogeschool (Wageningen), vol. 59 (13), p. 1-68.

4.- MOON, P., 1940.- Proposed standard solar-radiation curves for engineering use. J. Franklin Inst., vol. 230, p. 583-617.

5.- MOSS, R.A. ; LOOMIS, W.E., 1952.- Absorption spectra of leaves. I- The visible spectrum. Plant Physiol., vol. 27, p. 370-391.

6.- PESCOD, D. ; READ, W.R.W. ; CUNLIFFE, D.W., 1963.- Artificially lit plant growth cabinets. Proc. Symp. Engineering aspects of environmental control for plant growth. 1-5 September 1962, Melbourne, CSIRO, Engineering Section, Highett, Victoria, Australia, p. 175-195.

7.- VRIES, D.A. de, 1955.- Solar radiation at Wageningen. Meded. Landbouwhogeschool (Wageningen), vol. 55, p. 277-304.

TABLE 1 .- Relation between photometric and energy units for various lamps ($E_{400\_700/L}$ erg sec^{-1} Lux ^{1});relation between absorbable Einsteins and incident energy for a "normal" leaf ((Q $_{0}$/E) $_{400\_700}$ Einstein erg^{-1}) ; total flux of photosynthetically active energy emitted by lamps (100 $E_{400.700}$/W x 10^{7}). Between brackets : relative values, taking the average for all lamps = 100.

TL= Philips fluorescent tubes, 29 =worm white, 32 = w.w. de luxe, 33 = white, 34 = white de luxe, 55 =daylight, 57 =daylight special. HPL = Philips high pressure mercury vapour lamp, with fluorescent coating. Xenon : Osrom xenon lamp.

lamp type	E 400-700/ L	(Q_a / E) 400 - 700	100 E_{400_700} W x 10 ^{7}
TL- 29/40 W	2.81 (79)	3.68x10^{13} (99)	21.0 (116)
32	3.71 (104)	4.09 (110)	17.6 (97)
33	3.08 (87)	3.55 (96)	22.8 (126)
34	3.73 (105)	3.78 (102)	18.7 (l03)
55	3.72 (105)	3.60 (97)	20.0 (111)
57'	4.21 (118)	3.65 (98)	19.4 (107)
HPL/400 W.	3.02 (85)	3.57 (97)	15.5 (86)
Xenon/6000 W.	4.24 (119)	3.79 (102)	10.0 (56)
Sun	4.00 (112)	3.78 (101)	

TABLE 2 .- Electrical watts per m^{2} of the lamp assembly (W'watt m^{2}), total output of photosynthetically active energy by the lamp assembly (E_{400_700}erg cm ^{2} sec ^{1}); and efficiency of the conversion of electrical energy into photosynthetically active energy (100 E_{400_700}/ (W x 10 ^{7})).

The TL lamps are assembled in a horizontal plane, with 1 cm distance between the lamps. TLF =fluorescent lamp with internal reflector, HPLR = high pressure mercury vapour lamp, with fluorescent reflector. For other lamp specifications see Table 1.

Lamp type	W'	E 400 - 700	1 00 $E_{400\ 700}$ W x 10^{-}/
TL-33 /40W	690	15.8 x 10^{4}	22.8
TL-33 /80W	1110	22.3	20.1
TL-33 /120 W	1780	33.4	18.8
TLF-33/120 W	1780	28.3	15.9
8 x HPL / 400 W	3200	49.5	15.5
8 x HPLR/400 W	3200	40.0	12.5
1 x Xenon / 6000 W	6000	59.3	10.0
1 x Xenon /10000 W	10000	106.0	10.6

lamps. TLF = fluorescent lamp with internal reflector, HPLR = high pressure mercury vapour lamp, with fluorescent reflector. For other lamp specifications see Table 1.-

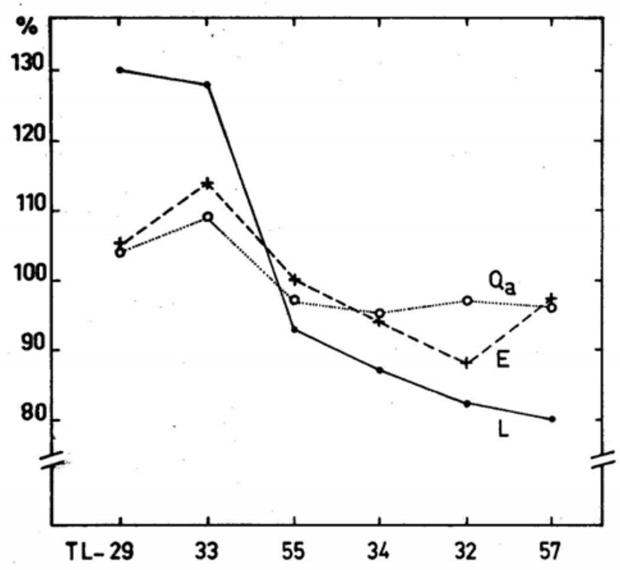
TABLE 3 .-Effect of the addition of incandescent lamps upon the spectral quality in the red (660 nm) and near in f ro-red (730 nm). The intensities are expressed in per cent of those for sunlight, taking equal energy fluxes for the photosynthetically active region.

((100 E_{660}, lamp + inc. /E 660, sun), For I_{400_700}, lamp + inc. = E_{400_700}, sun ; in the same way for E_{730}).

For each combination, the incandescent radiation added is expressed as the wattage installed in these lamps, in per cent of that installed in lamps of the other type.

Lam p type.	% installed in Inc. amps								r 660/ 730			
	0 %		20 %		40 %		60 %					
	660	730	660	730	660	730	660	730	0 %	20 %	40%	40%
TL-55 dayl. (new)	90	18	95	50	102	68	109	83	5,1	1.9	1.5	1.3
Ti.-55 " (old)	81	4	89	30	98	49	106	65	20.8	6.0	2.0	1.6
GE "	27	4	41	30	52	50	60	66	6.1	1.4	1.1	0.9
TL-33 white	45	4	56	30	67	50	73	66	10.2	1.8	1.4	1 .1
TL-32 w,w. do luxe	206	3	206	28	206	47	206	64	73.6	7,4	4.4	3.2
TL-29 w.w,	52	5	63	31	72	50	79	66	11.6	2.1	1.5	1.2
IL-34 w. de luxe	125	24	131	59	137	76	141	90	5.3	2.2	1.8	1.6
TL-57 doyl.spec.	81	11	88	41	95	59	102	75	7.1	2.2	1.6	1_4
Gro-Lux	210		216	24	213	43	219	60		9.1	4.9	3.7
Phytor	150	3	152	28	153	47	155	64	55.6	5.5	3.2	2.4
HPL 1961	139	7	141	35	144	53	148	69	19.6	4.1	2.7	2.1
HPL 1960	102	7	108	34	114	53	118	69	14.5	3.1	2,1	1.7
HPL 1955	117	9	121	38	126	57	132	72	12.5	3.2	2.2	1.8

Fig. 1 .- Radiation fluxes per lamp for various types of 40 W-fluorescent lamps. L = luminous flux per lamp ; E = energy flux per lamp ; Q_a = flux of absorbable Einsteins per lamp. For explanation of lamp type numbers, see table 1.-



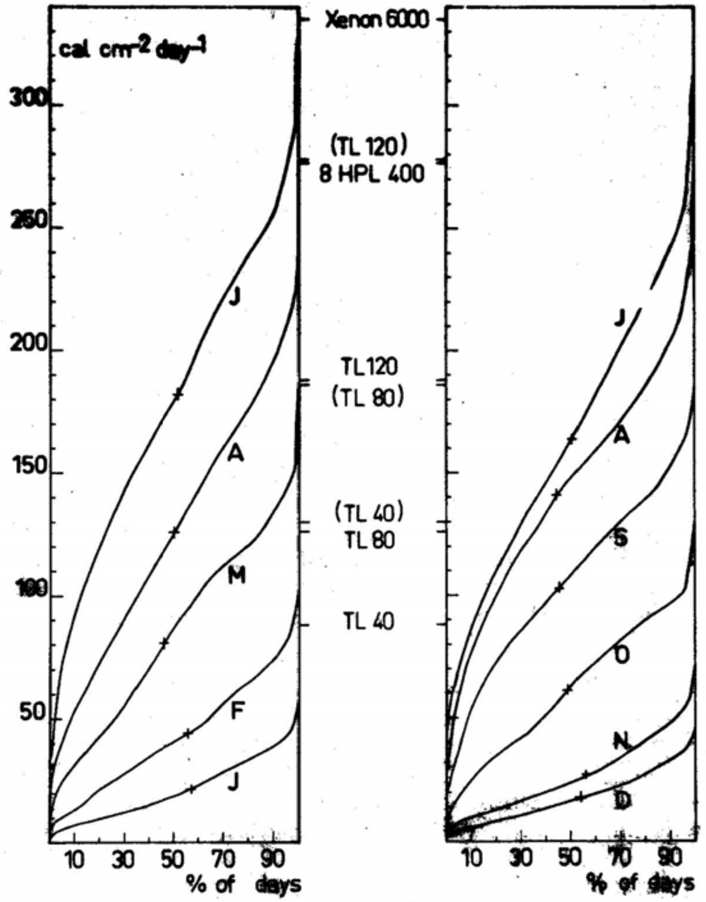


Fig. 2 .- Cumulative frequency distribution of daily irradiation (400-700 nm) at Wageningen, in comparison with daily irradiation obtained with various lamp types in growth rooms, during irradiation periods of 16 hours (lamp types without brackets) or 24 hours (lamp types between brackets).

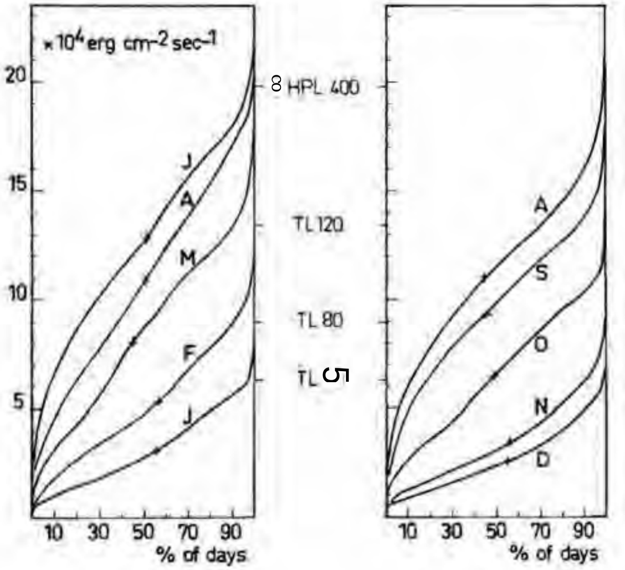


Fig. 3 .- Cumulative frequency distribution of average daily flux densities (400 - 700 nm) at Wageningen in comparison with flux densities obtained with various lamp types in growth rooms.

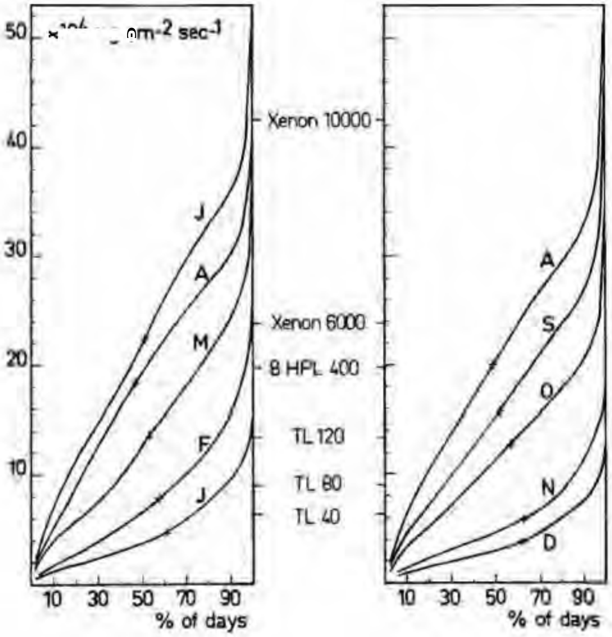


Fig. 4 .- Cumulative frequency distribution of flux densities (400-700 nm) at noon in Wageningen, in comparison with flux densities obtained with various lamp types in growth rooms.

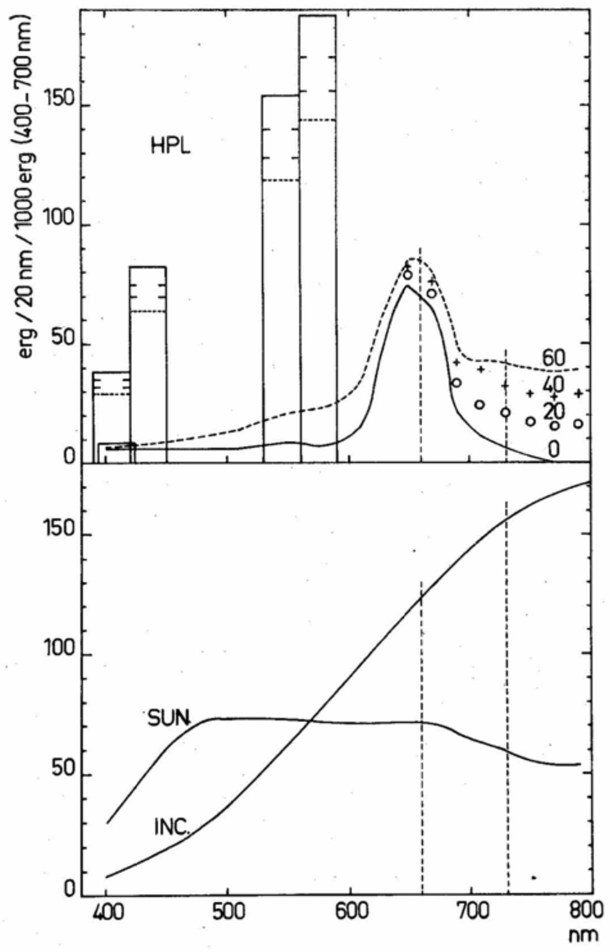


Fig. 5 .- Spectral energy distribution in radiation from the sun, from 100 W incandescent lamps, and from HPL lamps. The HPL lamps are mixed with various amounts of incandescent lamps. In all cases, the energy emitted between 400 and 700 nm is the same.

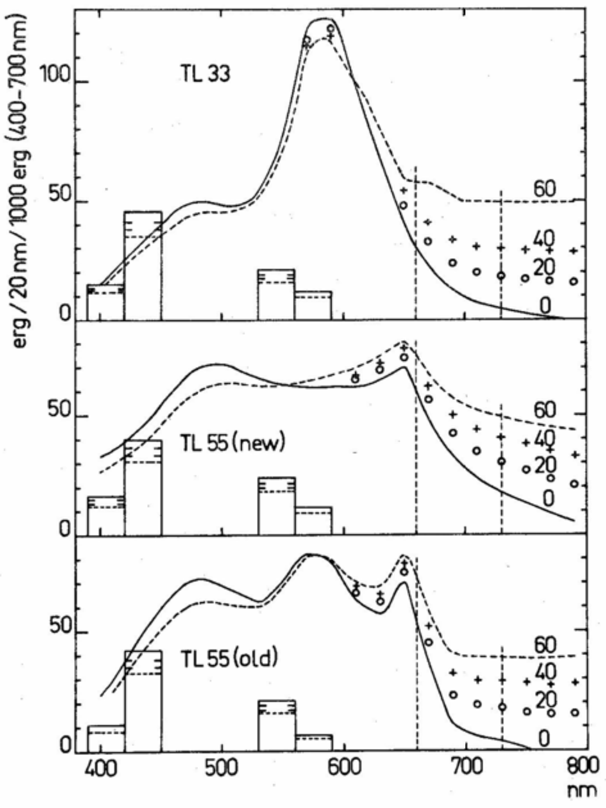


Fig. 6 .- Spectral energy distribution in radiation emitted by various lamp types, combined with different amounts of incandescent lamps. In all cases, the energy emitted between 400 and 700 nm is the same.

INFLUENCE OF CO_2 ON GROWTH AND YIELD OF OATS DEPENDING ON TEMPERATURE AND LIGHT INTENSITY

by

Prof. E. von BOGUSLAWSKI, Giessen.-

The effect of the growing-Factors, especially of some climatic factors upon the yield development cannot be observed isolated, that is independent of the effect of other foctors.(1) This is the cause of the importance of the rcrtios of the single factors to another (fertilizer ratio). (4). From the great number of growing factors can be defined, which have an especially narrow interaction.(1) Such groups are the chief-nutri ents nitrogen, potash, phosphorus and on the other side the climatic Factors light, temperature and CO_2 content of the air. (2) The factor water is connected with both groups by its physiological Functions. With respect to the latter group the older experimental results were concerned especially to measure the photosynthesis. At the first time our new experiments concerned the whole vegetation period and therefore also the yield-development. The phytotron enables us to observe such experiments throughout the whole vegetation period. We have found thereby that the phenomenon of the "complex effect" may be explained by the change of the development, the growth and the yield-structure, herewith the temporal-influence on the yield development in the course of the vegetation period on the one si de, and to the factors of the yield development on the other side may be explained (5) (3) Naturally there remains a "residual complex" of physiological processes which may be exploindes only in the whole.

Some time ago B. BRETSCHNEIDER-HERRMANN has investigated the interaction of temperature and CO_2 -content of the air, varying nitrogen fertilizer at the same time. (6) An increase of the CO_2 content to 0,15 Vol. % led to an increasing vegetative growth and to a greater height of the plant, as you can see for 1,2 g nitrogen from figure 1. This is right as well for the conditions of our normal climate as for a +8° increased temperature-climate.

An influence on the course of the development by CO_2 was not to be observed (see table 1) Therefore the straw-yields could be increased by the greater CO_2 -content. This effect was greater by increased temperature than by the normal temperature. The 2nd figure shows the yield-curves which are obtained with increasing nitrogen-fertilizer at the same time. The fact that the straw yields with a + 8° higher temperature were lower in general may be explained by the fact, that this temperature was not more optimal for oats and by the great development-acceleration therewith effected. By an increase of CO_2-content this decrease caused by the temperature can be compensated to a certain extent. This agrees with the result of LUNDEGARD who had observed, that with higher temperature also a higher CO_2 concentration has an effect.

We were surprised that in both temperature ranges the grain-yields of oats could not be increased by increasing CO_2 -content but were decreased especially with the lower nitrogen levels and reached with higher nitrogen levels the yield of the variants "without CO_2 -increase". These yields were with the normal climate in the maximum-range and with the + 8° higher climate already in the depression-range of the yield curve. Therefore the further CO2-increase had influenced the grain development in the ascending part of the yield-curve in a negative sense. This was especially the fact with the higher straw-development in the combination of 8° higher temperature and a higher CO_2 -content, in which also higher nitrogen levels could not compensate this negative influence. By an increase of CO_2 therefore a decrease of the grain production per unity of straw (grain/straw) was observed as you can see from table 2. Now after we hod found, that the influence of the CO_2 -concentration on the development can be neglect-ed, there is the question, whether a variation of the temperature and in the same time of the nitrogen fertilizer has an effect on the development. We know from other experiments, that nitrogen accelerates the development in the earlier stages, whilst it retardes the development in the maturation-phase, that is in the phase of the grain development. Here we Find optimal curves. In our experiments we Found a retardation with increasing nitrogen fertilizer as you can see From table 1. So we cannot explain the low yields of the grains by this Fact. Also the differentiation of the inflorescens, that is therumber of the grains per panicle agrees with a retarding effect of the nitrogen and cannot explain the lower grain yields. As we can see from table 2 by the increase of CO_2 the number of grains per particle was increased in both temperature-levels. Therefore the lower grain yields result only from the lower 1 000-grain- weight. The increase of the temperature -this to a greater extent- and the CO_2 -increase effect in the some direction a worse grain development. We can seek out the cause of this fact and therewith also the lower groin yields in the worse use of the nitrogen fertilizer for the grain development. In spite *of* higher straw-yields and ❑ better utilization of the absorbed nitrogen the nitrogen-use is decreased with CO_2 supply. Probably this is a consequence of the vegetative growth process caused by the CO_2 concentration,so that the development of the greater grain-number is reduced. This would be possible also independent of the temporal influence of the temperature upon the course of the vegetation.

Our new experimental series treats the connection of CO_2 -content in the air and the intensity of the light. The CO_2 -content was increased to 0,30% vol. % and compared with the normal content, while the light intensity was increased to 25.000 Lux and compared with 20.000 Lux ("normal"-climate}. Six harvesting-times were employed with a nitrogen level of 1,6 g N/pot. The most important results you con see From Figure 3. Already in an earlier stage of the vegetation we find significant differences in development and moss-growth, which increased in the vegetation.

As well the increase of the light-intensity as of the CO_2 -concentration increased the yield and at the end of the vegetation the CO_2 -effect was significantly better than that of the lighl intensity. In the contrast to the normal climate the two factors can therefombe compensated on the base of the other conditions during the whole vegetation period. The vegetation time resp. the development was shortened *for* 2 - 6 days by the higher light-intensity in the presence of CO_2 this effect was removed. The increase of nitrogen had again retarded the development to some extent.

The clear picture thus obtained is again complicated -in analogon to the former experimental series- by the different influences upon straw and grain. By an increase of the light-intensity both the components were increased in a similar manner as you can see in table 3 for the factor grain/straw. For the 2,0 g N-level this factor is even increased. By the higher CO_2 -concentration the grain yields are either decreased or only increased to a small extent, while the straw yields are increased to a great extent. This was also the case in the Former experimental - series. With the combination of light and CO_2-supply these changes were found more significant, so that also in this case the lower factors were calculated for the ration grain/straw. The groin number per panicle is also increased by an CO_2-increase in accordance to the former experimental series. So the lower grain yields may be deduced from a lower 1000-grain- weight.

An exception from the just told facts could be observed with the highest nitrogen level of 2,0 g/pot. This level influences with higher CO_2 -concentration again an increasing grain yield so that the yield curve becomes steeper and S-shaped. While with the light intensity only the increase of the yield-curve looks like we would expect, and has already a depression for "normal climate", the Factor grain/straw and the 1000-groinweight are much more better.

The phenomenon just told may be the key for an exploration of the dependences

In both the experimental serieses a strong overweight of the vegetative parts of the plant in the sense of a "physiological change" is excited by the increase of the CO -content of the air. In spite of the increase of the grain number per panicle we find lower groin yields because of the bad development of the grain, that is a worse 1000-grain-weight. This depends at the same time from the worse nitrogen-utilization for the grain development. For this development a relative nitrogen-deficiency arises with lower nitrogen levels, while higher nitrogen levels help to remove this deficiency, so that the grain yields increase. In the first experimental series we could observe this only weakly, because the higher temperatures had *a* negative *effect* on the yield of oats. In the second series this phenomenon could be observed better, because in this series light-intensity and CO_2 -increase worked in the same direction (positive). In the right combination (relation) of these two factors *the* CO_2 factor seems to *be* crucial for the form of the complex-effect.

DISCUSSION .-

Koller .-in experiences it is not sufficient to have two points or two concentrations of any one factor because you *m7:17¯ge* working on two sides of the optimum and get misleading results. At least three points would be required before you can draw any conclusions.

Baguslovsky .- *We* have results of all factors and I would only soy to demonstrate that when you will have a conclusion you must have not only one factor but two or three cases and on the other side you must hove a curve and when you have *a* curve you cannot have a mistake for the conclusion.

BIBLIOGRAPHY .-

1.- BOGUSLAWSKI, E.V., 1954 .- Das Zusammenwirken der WachsturnsFaktoren bei der Ertragsbildung. Zt. F. Acker-u. Pfltb. 3d, 98, 5.145-186.

2.- BOGUSLAWSKI , E.V., 1959.- Zur Problematik der Pflanzenbauwissenschaften. Zt. f. Acker- v. Pflzb. Bd. 108, S. 321-338.

3.- BOGUSLAWSKI, E.V. ; A. VOrnel u. G. Reichelt, 1954: Nahrstoffverleltnis in der DFngung Lind Ertrogsbildung, Zt. f. Acker - u. Pflzb. Bd, 97, S. 267-2%.

4.- BOGUSLAWSKI, E.V., 1961.- Zur Zielsetzung der Forschungsarbeit in Rauisch-Holzhausen, Ber. d. Oberh. Gesell. F. Natvr.- u. Heilkunde zu Giessen, Bd. 31.

5.- BOGUSLAWSKI, E.V. ; P. LIMBERG, g .B. SCHNEIDER, 1962/63 .- Grundfragen and GesetzmdBigkeiten der Ermagsbildung. Zt. f. Acker- u. PFIzb. Bd„ 116 S. 231-256.

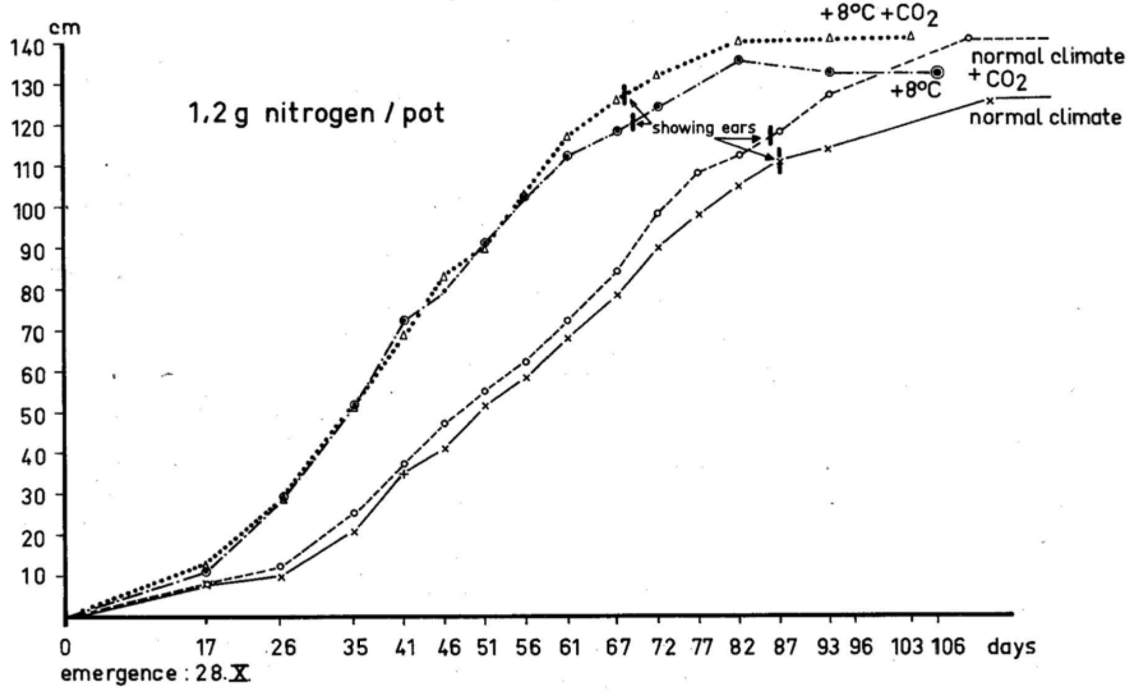
6.- BRETSCHNE1DER-HERRMANN, B., 1962/63 Uber die Wechselwirkung von Temperatur and Kohlensduregehalt der Luft our Hofer. Zt. f. Acker - u. PFIzb. Bd 116 S. 301-316,

o o

Fig. 1

pot experiment P VI/61

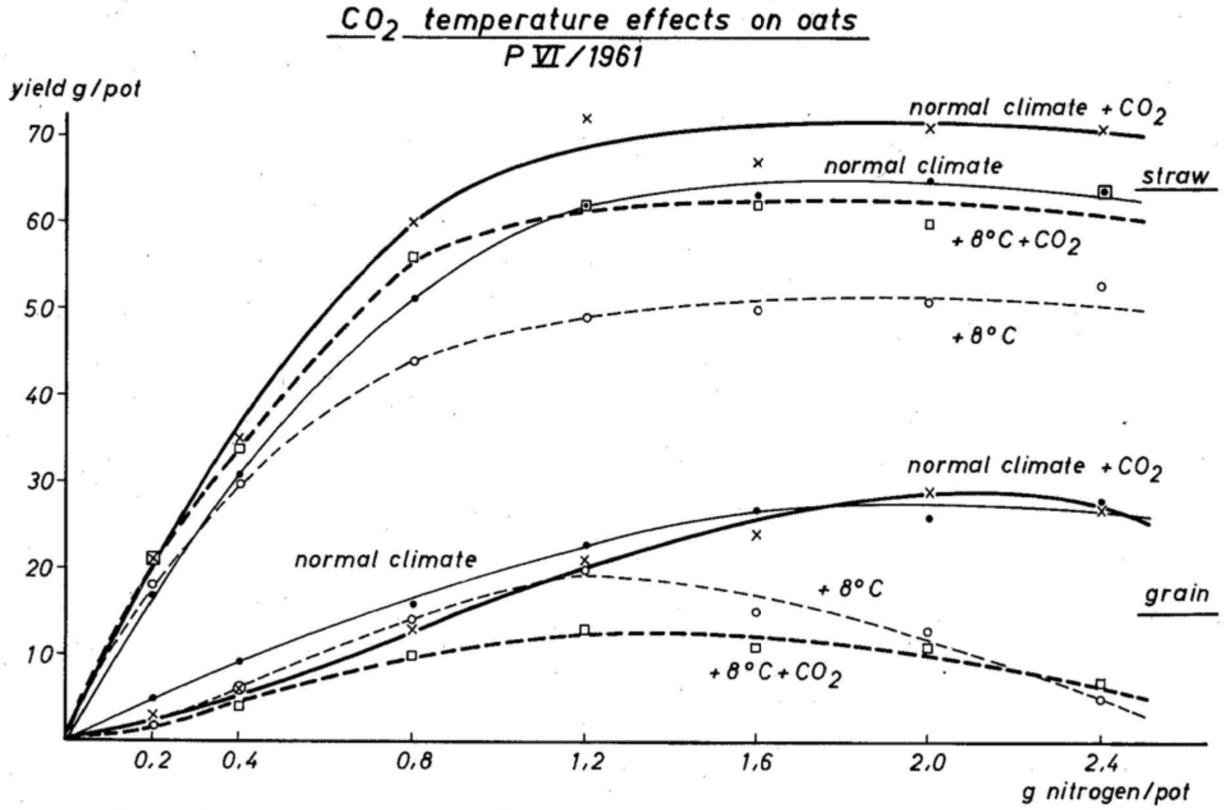
length of growth



Tab. 1

pot experiment P VI/61 days of vegetation					
Nr.	g nitrogen per pot	normal climate	normal +CO_2	+8° C	+8° C +CO_2
	from emergence to heading				
1	0,2	83	82	65	64
2	0,4	84	83	66	65
3	0,8	87	84	68	67
4	1,2	87	86	69	68
5	1,6	85	87	72	68
6	2,0	88	87	74	69
7	2,4	90	88	73	69
8	1,6 – H_2O	76	86	71	68
	from heading to yellow ripeness				
1		41	41	27	27
2		43	42	28	28
3		42	41	30	30
4		43	40	32	30
5		47	43	33	36
6		47	49	35	38
7		50	47	35	44
8		46	45	34	36
	from emergence to yellow ripeness				
1		124	123	92	91
2		127	125	94	93
3		129	125	98	97
4		130	126	101	98
5		132	129	105	104
6		135	136	109	113
7		140	135	109	113
8		122	131	105	104

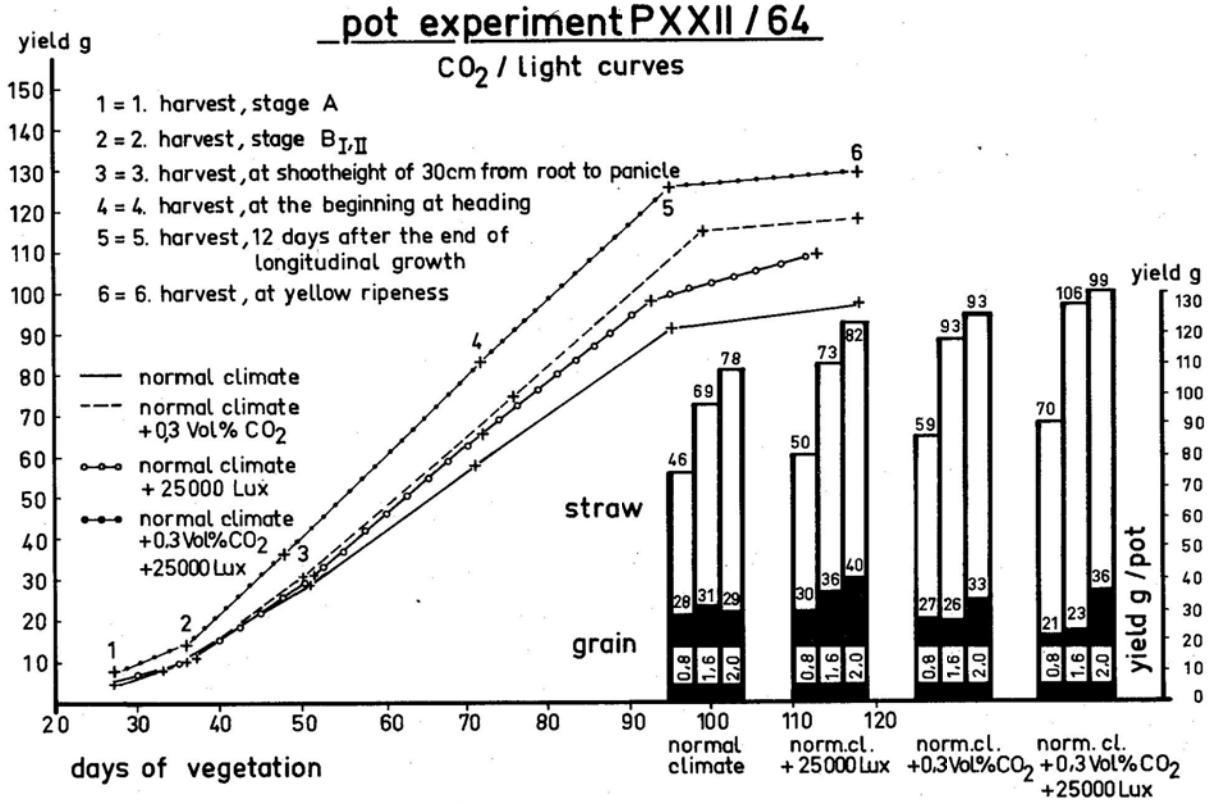
Fig. 2



Tab. 2

pot experiment P VI /61				
	ratio grain : straw			
g nitrogen per pot	normal climate	normal + CO_2	+ 8°C	+ 8°C + CO_2
0,2	0,274	0,155	0,111	0,078
0,4	0,304	0,165	0,211	0,123
0,8	0,311	0,221	0,311	0,169
1,2	0,367	0,192	0,420	0,212
1,6	0,430	0,353	0,291	0,173
2,0	0,400	0,423	0,261	0,177
2,4	0,430	0,382	0,096	0,108
M: 1,2	0,359	0,276	0,243	0,149
	weight of 1000 grains (g)			
0,2	16,1	10,4	7,3	5,6
0,4	17,8	10,4	14,6	6,7
0,8	19,8	13,5	12,7	8,4
1,2	27,2	13,4	20,1	8,9
1,6	29,6	21,6	15,5	6,6
2,0	22,3	22,3	15,1	7,5
2,4	26,1	20,5	10,0	9,1
M: 1,2	11,7	16,0	13,7	7.5
	number of grains per panicle			
0,2	10	12	10	10
0,4	20	19	15	24
0,8	29	35	37	40
1,2	30	49	35	51
1,6	28	39	34	57
2,0	40	46	32	52
2,4	36	47	18	27
M: 1,2	29	37	26	37

Fig. 3



pot experiment PXXII / 64

CO_2 / light curves

Tab. 3

pot experiment PXXII/64				
	ratio grain : straw			
g nitrogen per pot	normal climate	normal cl 25000 Lux	normal cl. +0,3 Vol % CO_2	normal cl. +0.3%Vol CO_2 + 25000 Lux
0,8	0,62	0,59	0,46	0,30
1,6	0,45	0,48	0,28	0,22
2,0	0,37	0,48	0,35	0,36
	weight of 1000 grains			
0,8	17,2	20,9	17,0	15,0
1,6	19,7	18,3	14,2	11,5
2,0	15,3	19,2	18,9	15,1
	number of grains per panicle			
0,8	53	46	49	48
1,6	35	37	48	47
2,0	33	32	43	46

GENETIC VARIATION IN DEVELOPMENT RESPONSES TO LIGHT AND TEMPERATURE

by

Dr J.P. COOPER, Welsh Plant Breeding Station, Aberystwyth.

It has been emphasized several times in these meetings that the design of a phytotron will depend very largely on the purpose for which it is to be used. I would, therefore, like to discuss some of the ways in which controlled environments can be used in studying genetic variation in crop plants and also the way in which its use a breeding programme will affect some of the points of design.

Crop production is basically the use of solar energy to produce human foodstuffs or industrial raw materials, and the primary climatic limit to production is therefore the seasonal distribution of energy in any particular locality. The ability of the plant to make use of this energy can, however, be restricted by two other important climatic factors, low temperature and water supply. The plant breeder is therefore basically concerned to develop varieties which possess those physiological responses which give the most efficient conversion of his seasonal range of energy income, and at the some time are either tolerant to or avoid any limitations of cold or draught. Genetic variation provides the raw material for any breeding programme and a knowledge of the variation in response to climate in his crops and in related wild species is therefore very important in planning advanced programmes of plant introduction, selection or breeding.

Such study involves three levels of investigation on the part of the breeder and the crop physiologist, firstly, an investigation of the climatic limits to production in his particular locality in terms of solar radiation income through the year, temperature limits, and water supply, secondly, a survey of the field performance of varieties of his crops and of closely related wild species, and thirdly, a study of the physiological basis of these differences in performance with a view to selecting material with increased physiological efficiency. It is at this third stage that the phytotron can be most valuable as an experimental tool in a programme of crop improvement.

I would like now to give a short outline of this ***sequence*** as applied to the grass breeding programme at Aberystwyth with particular reference to the problem of winter production. This problem is of considerable economic importance in Britain, and at the same time is of basic physiological interest. At the high latitude of 52°N. the main limitations to production in the winter are (i) o low energy income, often less than 50 cal/cm^2/day, compared to a summer figure of between 450 and 500 cal/cm^2/day and (ii) low temperatures, although not usually low enough to require extreme cold resistance. The mean January temperature at Aberystwyth is about 5°C. which is not low by continental standards. An important production problem is therefore to make the most efficient use of this low energy income in the winter. In recent years, attention has been given to the possibility of using Mediterranean ecotypes of many of our important forage grasses such as Lolium perenne, Dactylis glomerate and Festuca arundinacea (Borrill 1961 ; Knight 1963). A number of collecting expeditions, including a joint CSIRO/FAO Expedition, have brought back material which on being tested at Aberystwyth and the Grassland Research Station at Hurley and elsewhere, showed, in most years, increased production during the months of January, February and early March compared to indigenous British varieties.

These findings raised two important problems (1) what is the physiological basis of this increa-

sed winter performance and (2) how can we best use it to improve our existing varieties. I will briefly describe the sequence which we have adopted in studying this material (Cooper 1965). Firstly, we needed information on the climatic background and particularly the climatic limitations to production. In the Mediterranean environment of Algiers we find a range in the energy income from about 250 cal/cm^2/day in winter to 700 or 750 in the summer. The corresponding Figures for Aberystwyth range from about 50 cal/cm^2/doy in the winter to 400 in the summer, so the potential production for any crop in terms of energy income is higher in Algiers than in Aberystwyth. On considering the other limits to production, however, we find that except under irrigation conditions production is limited in Algiers in summer because of drought, but there is little or no winter limitation due to low temperature. In Aberystwyth, on the other hand, the mean temperature falls to about 5°C. in January, with an appreciable effect on crop growth. In the east of Britain the situation is more extreme and winter temperatures are more limiting. The total available radiation per annum, however, in the absence of irrigation, is not very different in the two locations since in Algiers it is mainly winter radiation which is available and in Aberystwyth summer radiation.

The field performance of a adopted varieties from these contrasting climates has already been mentioned. In Lolium, Festuco and Dacytl is, agronomic trials show more active leaf growth during the winter in the North African material than in the indigenous British varieties.

The physiological analysis of these differences in winter production involves both glasshouse and phytotron studies. The first stage was to take typical Mediterranean, maritime and north European ecotypes of these three species, Lolium perenne, Decrylis glomerate and Festuca arundinacea, and study their growth and development in an unheated glasshouse through the year (MacCoif 1965). We used the classical growth analysis techniques on serial sowings made over a period of two years, and found, as might be expected, that the relative growth rate was lowest in January, it rose to a maximum in June or July and fell again in December. The seasonal curve was the some form for the Mediterranean and northern material, but in the winter the relative growth rote of the Mediterranean ecotype was considerably higher than that of the Northern. By growth analysis techniques we can analyse the relative growth rate into net assimilation rate, which is a measure of photosynthetic activity per unit of leaf area, and into leaf area ratio, which is a measure of the proportion of the plant which is photosynthetically active. The curve for net assimilation rate followed very closely that for incoming radiation, but there was little if any difference in the net assimilation rate between the different ecotypes ; if anything, the northern ecotypes were slightly higher in the winter. Leaf area ratio, however, showed the reverse picture, being higher in the winter and lower in the summer, with a small amplitude in the northern varieties but very large seasonal differences in the Mediterranean material. The conclusion drawn from this work is therefore that these differences between the Mediterranean and northern ecotypes in winter growth rate were based, not on differences in photosynthetic activity, but on the difference in expansion of the leaf surface under winter conditions.

This difference in leaf expansion could, however, be a response to photoperiod, to total light energy or to temperature, to the next stage of the work was carried out in controlled environments in which these effects could be separated (Cooper 1964). The first step was to measure leaf expansion at a series of controlled temperatures (5°, 10°, 20°, 30°C.) in a 16 hour photoperiod of about 800 ft. candles. We Found that the optimum temperature for expansion of the leaf surface in all varieties was about 20°C., with a reduction at 10° and even more so at 5°C. There were, however, regular differences between these ecotypes in the degree of reduction at low temperatures. Comparing Algerian and Danish ryegross, for instance, leaf expansion was similar for both ecotypes at the optimum temperature, but at 5°C. there was a three-fold difference in favour of the Algerian material. We also studied the effect of supplementary photoperiod, continuous light compared to 8 hours, on these ecotypes, but found no differential responses to photoperiod in terms of leaf expansion. This difference in winter growth thus seems to be largely a response to temperature, which acts developmentally on leaf length (i.e. cell expansion) rather than on leaf width or rate of leaf appearance.

A further part of the investigation which was also carried out in controlled environments was to measure the rates of photosynthesis and respiration of these ecotypes (Eagles 1960. This has so far only been done for two varieties of Lolium perenne, one from Lithuania and one from Algiers. The photosynthesis response curve was Fairly flat for bath the northern and Mediterranean material over the temperature range 5°, 10°, 20° and 30°C., but there was an indication of a higher optimum temperature for the Mediterranean ecotype. The differences in respiration rate, however, were quite marked. At low temperatures (5°C.), the northern ecotype had a much lower respiration rate than the Mediterranean, and at the same time accumulated high concentrations of soluble carbohydrate at the base of the shoot, where as the Mediterranean material showed rather less accumulation.

The conclusions that we can draw are that these differences in winter growth in the field, are due not to differences in rate of photosynthesis between the two climatic groups, but to variation in the *way* in which assimilates are used. In the Mediterranean material, assimilates appear to be used actively for leaf expansion with a high respiration rate but less accumulation of soluble carbohydrates. *In* the northern material, the assimilates are not mobilized for leaf expansion, the respiration rate is low, and carbohydrates are built up in the base of the shoot, with associated frost resistance.

This type of investigation outlined above shows that phytotron equipment can be of considerable importance to the geneticist and plant breeder both in the analysis of his breeding material and in the development of screening tests. Such work, however, make certain demands on the design of controlled environments

(ill we are concerned with comparing varieties, or segregating families, and therefore need large rooms, though possibly a smaller number since we ore interested primarily in a small er of stress environments.

(ii) since ***at*** a latitude of 52°N. we have a large seasonal fluctuation in energy income, we need high intensities of artificial light in order to have controlled and reproducible energy input.

(iii) for screening purposes we are not interested in very close control of temperature and for many of our purposes humidity control is not particularly important.

DISCUSSION

Birch .-We are carrying out work on North African *fescues* at Cambridge also and Dr Cooper's paper brought up several interesting points. I think it important to show that the results being obtained in artificial conditions are similar to those that one would expect in natural environment. Eventually it is hoped that the artificial environment will be used for selecting grasses for winter production as well as giving an indication of the physiological basis for the differences between these species or varieties. Any particular selection must be carried out under a specified set of conditions, for the relative superiotity of different varieties depends upon the environment in which the selection takes place. We have carried out a series of experiments in which we have taken the plants gradually from the uncontrolled environment in the field and by a series of steps put them into controlled environments. There are two principal ways in which you can examine the effect of environment on a plant ; firstly, you can make a direct analysis of the natural environment and the growth of the plant, secondly, you can grow the plant under a range of controlled environments. In the first approach, the difficulty is that climatic variables tend to fluctuate together. It is difficult to separate out the effects of different variables, and in addition elaborate equipment is required for continuous recording of the environment. In the second approach you have to know the exact levels of environmental factors that need to be controlled.

We have, therefore, grown plants during the autumn in the natural environment outdoors and noted the date when the difference in relative growth rate between the North African fescue and the British 5.170 first appears. We recorded the environment at that time, including light intensity, day length, and night and day temperatures. The next step was to control the least variable of these factors, in this case, night temperature. Having defined the night temperatures, which would result in a difference between these two varieties under natural conditions, the material was then transferred completely into the controlled environment. The results that we have obtained to date differ somewhat from Dr Cooper's. We find that the difference between our two varieties appear to be related to net assimilation rate. The North African variety has a higher leaf area ratio than the British variety, but this is relatively small compared to the large differences in net assimilation rates. We have also studied the effect of day-length in the glasshouse, using supplementary low intensity light under different night temperature regimes. Under high night temperatures, supplementary low intensity light of 50 ft. candles for 6 hours tripled the dry weight of the British variety in a matter of two months.

Lang .- I think you have brought up one very important point ; how can the results of phytotrons be projected back into nature, i.e. to what extent it is possible to duplicate natural conditions ?

Wassink .- I am surprised that there is so little temperature effect on photosynthesis. That would, in my opinion, mean that there is a strong limiting factor, such as light intensity, or CO_2 deficiency -is that possible ?

Cooper .- This particular run was carried out at between 800 and 1000 ft. candles, so the light energy is certainly low. We are extending this work using stronger light sources, but are still in the process of building a circuit which will eliminate CO_2 depletion.

Wassink .- This is the logical consequence of the shape of the photosynthesis curve which has the temperature independent part at low light intensities, and the temperature dependent part at high light intensities.

If your light is limiting, it is not quite clear whether there is a difference in photosynthesis between the two strains with regard to temperature ; it may simply be in respiration.

Cooper .- The data refer to true photosynthesis, corrected for respiration.

Boguslawski.- I would ask if you have different levels of nitrogen in this experiment, because we have a type of Mediterranean wheat which shows a great effect in the response to low temperature when you give it more nitrogen.

Cooper .- This work refers to seedling material grown at fairly high levels of nitrogen in the standard John Innes compost which we use for most of our experiments. In connection with the effect of a low intensity supplementary illumination on increased growth, we also find that using a supplementary low intensity tungsten light of 40 to 50 ft. candles gives a marked increase in leaf expansion. A greater dry weight may result simply from an increase in leaf surface rather, than in photosynthesis.

Lang.- I think the point that Dr. Wassink brought up deserves great attention in that greatest response will be obtained in conditions not limited by other factors. Preliminary comparisons between different alfalfa strains in our phytotron, for example, have shown that the light intensity made a large difference as to whether the temperature response of the different strains become apparent or not. We found very little difference in glasshouse conditions, but large differences at the higher light intensities of the growth rooms.

BIBLIOGRAPHY

BORRILL, M., 1961.- Grass resources for out-of-season production. *Rep. Welsh Pl. Breed. Sta.,* 1960, 107-111.

COOPER, J. P., 1964.- Climatic variation in forage grasses. I. leaf development in climatic races of Lolium and *Dactylis. J. Gael. Ecol.,* 1, 45-61.-

COOPER, J.P., 1965.- Climatic adaptation of local varieties of forage grasses. in *Biological significance of climatic change in Britain.* - Academic Press., London (in press).

EAGLES, C.F., 1 964.- Photosynthesis and respiration in climatic races. *Rep. Welsh Pl. Breed. Sta.-,* 1963, 20-21.

KNIGHT, R., 1%3.-A comparison of seasonal plant growth in a northern European and a Mediterranean climate. *Rep. Welsh Pl. Breed.* Sta., 1962.- 102-114.

MacCOLL, D., 1965.- The growth of varieties and climatic races of herbage grasses. *Ph. D. Thesis,* University of Wales.-

⁂

PROBLEMS OF FUNDAMENTAL AND APPLIED PLANT PHYSIOLOGY WHICH REQUIRE CONTROLLED ENVIRONMENT

by

Prof. K.K. NANDA Depart. of Botany, Panjab University.-

In the sessions on the "Round Table on Phytotionics" held yesterday and this morning, various speakers described the essential features of different phytotrons that have been built for various research purposes in different parts of the world. The technical problems relating to the control of different factors of environment, the various difficulties that were met with in the design of these controls and the manner these difficulties were overcome, were also brought out during these sessions. These discussions are useful for all concerned with phytotronics in some way or the other but are of particular significance to those of us who, although do not possess such facilities at present, expect to have them in a not distant future. The negotiations for construction of a phytotron in India with the assistance of the Government of Australia are already in progress and we hope to benefit a lot from these experiences.

All those who plan to build a phytotron are confronted with the problem of deciding upon the type it should be. Should it be of Pasadena type with a number of rooms maintained at set conditions and with provision of trolleys for transferring plants from one condition to another ; or should it have a large number of cabinets each under individual control and each capable of providing a wide range of conditions so that plants are not required to be shifted as in Canberra or should it be a "super type" which is less expensive but in which the control may be less precise. The discussions of yesterday and this morning have revealed that there is no ready made prescription or standard of a phytotron which may be recommended to be built. What type it should be very much depends upon the type of work that is to be carried and the materials that are to be worked with. According to Lang (1) before designing a phytotron it is absolutely essential to define in broad but still specific terms the research purposes which it is to serve. While it may be true in principle it is very difficult to define even very broadly the research projects that will be undertaken, as in a country like India which can not afford a separate phytotron for each research purpose, the facilities of the same phytotron will have to be used for problems, very diverse in nature and involving investigations on diverse plants. The design of the phytotron, therefore, will have to be adequately flexible so that different problems can be undertaken without involving any major changes in the design.

The problems in plant physiology, both fundamental and applied, which require control of environment are numerous. These were adequately discussed in a symposium on "Environmental Control of Plant Growth" that was held to celeberate the successful design of the "CERES", the Canberra Phytotron, in September 1962. In view of the exhaustive account that is available on this topic (2), I have decided to divert a little and to discuss in this paper some of our work on problems of growth and development carried out during the last about 25 years with a two-fold objective, firstly to demonstrate that very useful work can be done even when facilities for controlled environment are not available, and secondly to show that in the course of research sooner or later a stage is reached when such facilities become essential of a headway in research is to be maintained. The answers to many questions that have emnated from these investigations can be provided only with experiments conducted under controlled conditions.

This work was initiated by Chinoy at the Indian Agricultural Research Institute, New Delhi in 1941 and has been continued by him and his co-workers including the author at different research centres in the country.

GROWTH AND DEVELOPMENT .-

Two hundred and sixty varieties of wheat, both indigenous and exotic, were grown with a view to selecting the suitable ones for breeding work. Periodic observations on growth characters were made. The period elapsing from sowing to anthesis (vegetative period) and from anthesis to maturity (ripening period) were calculated. Records were also maintained of the daily photoperiod and maximum and minimum temperatures during the growing period. As the data was very extensive varieties were divided into a number of flowering classes on the basis of the length of their vegetative period, which varied from 100 to 220 days.Thus, varieties flowering within 100-110 days were grouped together in one class, those within 111-120 into the second and so on. These were, therefore, grouped into 12 Flowering classes. When the data was compiled it revealed that various growth characters such as height, tiller and leaf number, fresh and dry weights of stem, leaf and root ***were*** all correlated with the length of the vegetative period. Thus,the early flowering varieties exhibited a very rapid rate of stem elongation and had a few tillers and leaves as against the late flowering ones which remained in a prostrate condition for a long time and produced o large number of tillers and leaves (3). It was also found that the number of ears produced on a plant, the number of spikelets and grains, the thousand grain weight and the yield were correlated with the temperature of the ripening period. These were all low in the late flowering varieties as the temperature during their ripening was very high. On the other hand, in the early varieties which ripened at a lower range of temperature, the grain was plump and the number of ears, spikelets and the grains produced was more and ultimate yield was higher (4,5 and 6).

The relationships were confirmed in two ways : (i) By growing varieties belonging to different flowering classes under varying combinations of vernalization and photoperiodic treatments to alter the length of the vegetative period (5, 6, 7, 8, 9, 10 and 11). It was found that when a late flowering variety was mode to flower early, it behaved like a variety of this flowering class in its growth. Thus, it shot up early and produced only a few tillers and leaves as is shown **in** Fig. 1. The grain also became plump and the yield was more. On the other hand an early variety when made to flower late behaved like a late one. The rate of stem elongation became very slow and the number of tillers and leaves produced very high. The groin became shrivelled and the yield was consequently lowered (Fig. 2).

(ii) By making crosses between varieties of different flowering classes and observing segregation of growth, flowering and yield characters in F_1 and F_2 generations. It was found that in a cross between late and early varieties the range of character variation in F_2 generation was very wide and plants showed the same correlations between growth and development as well as between yield and temperature of the ripening period as the parents. Thus, for example, never a segregate was found which flowered in 100 days and had a very large number of tillers nor one which flowered in 200 days and had just o few tillers (12,13).

METABOLIC DRIFTS AND DEVELOPMENT .-

The metabolic drifts of nutritional substances, both organic and mineral, as well as of regulatory substances like auxin and ascorbic acid in different varieties grown under varying combinations of vernalization and photoperiodic treatments also revealed correlations with flowering (14, 15, 16, 17, 18, 19, 20 and 21). Thus, for example, the relative rates of uptake of nutrients such as N, P or K and the increase in the ratio of their contents in stem/leaf were faster in early flowering varieties and very slow in the late flowering ones. When a late flowering variety was mode to flower early, the rate of uptake of these nutrients as well as their ratio in stern/leaf become fast. On the other hand, when an early variety was made to flower late these were also slowed down. The changes in the ratio of contents of N,P and K in stem/leaf of a variety subjected to three photoperiods are shown in Fig. 3. Similady shifts occured in the metabolic drifts of auxin and ascorbic acid of a variety when the time of flowering was altered by exposing it to different combinations of vernalization and photoperiodic treatments (Fig. 4).

The length of the vegetative period of a variety which is of such paramount importance in determining the rate and magnitude of different components of growth and metabolic drifts of nutritional and regulatory substances was found to be related with the length of the photoperiod to which it was exposed. The longer the daily photoperiod, the earlier was the flowering and vice versa, suggesting a quantitative relationship between the light energy utilized by the plant and its vegetative period. A hughly significant correlation was also found to exist between the photo-quantum (the sum of light hours during the vegetative period) and the thermic-quantum (sum of daily mean temperature during the vegetative period). The amount of energy received by different varieties of wheat belonging to different flowering classes during their vegetative periods, when subjected to different vernalization and photoperiodic treatments, were determined by multiplying the photoquontum of a variety with its thermic-quantum. This product which is termed"photothermic quantum" was found to increase with the length of the vegetative period of a variety and was constant for a variety grown under varying photoperiods (22). It means that a given variety requires a certain amount of photothermic energy to complete its developmental process. It will flower early if this quantum of energy is provided early and late if it is completed late. These results, thus, lead to the conclusion that varietal differences in the rates of uptake of mineral nutrients, in the rotes of production and utilization of orgonic materials including regulatory substances, growth in its different components, flowering and yield are all resultant of a coordinated metabolic system which is dependent upon incorporation and utilization of external energy.

PHOTOTHERMIC QUANTUM AND PHYSIOLOGICAL CLASSIFICATION .-

The relationship between the vegetative period (F), photothermic quantum (E), mean temperature (t) and mean photoperiod (p) of the vegetative period can be expressed by the formula :

$$E = F^2 pt$$

or

$$F^2 = \frac{E}{pt}$$

or

$$F = \sqrt{\frac{E}{pt}}$$

It means that if the photothermic quantum of a variety is known, the approximate length of the vegetative period at any place can be calculated from the formula, provided the mean photoperiod and the mean temperature of the growing period of that place are known. Further by knowing the correlative nature of growth and flowering, the growth performance of the variety can also be predicted. The photothermic concept may, thus, be useful in the classification of varieties in terms of their energy requirement (23).

GROWTH PATTERN AND REPRODUCTIVE DEVELOPMENT .-

Studies on relationship between growth and development were extended to a large number of other plants. Thus, six different types of millets were grown at 32 days intervals throughout the year. The growth pattern of one of these -Ranicum miliaceum- is shown in Fig. 5. The ears of this and Fleusine coracana in different sowings are also shown in Fig. 6 and 7 respectively. Marked differences in the growth pattern of these plants and the morphology of their ears observed with a change in the time of sowing are a consequence of alterations in the pattern of lateral bud development. Thus, in early sowings the development of lateral buds is confined to the lower part of the plant prior to flowering and occurs in acropetal order. On the other hand, in later sowings lateral buds elongate only after the emergence of the ear of the main shoot and occurs in basipetal order from top downwards. As a consequence of this the growth pattern varies remarkably in plants of different sowings (24). That the emergence of lateral branches and their flowering is also correlated with the flowering of the main shoot, is clearly brought out from another experiment in which plants were subjected to varying photoperiods, The results are shown in Fig, 8. Plants exposed to long day condition (LD) did not flower at all and branches emerged one after another in acropetal succession. But in plants exposed to normal day (ND) and short day (SD) the development of branches took place in basipetal succession, and occurred after the emergence of the ear of the main shoot. The emergence of secondary and tertiary branches and their flowering also followed the same pattern as the primary branches (25).

Similar relationship of branching pattern with flowering has been observed in other plants including some forest plants (26, 27, 28). In Crotalario (Emcee he branches remain very small and arise in basipetal order during the time of the year environmental conditions ore inductive but elongate even 4-5 times the length of the main shoot with complete arrestment of lateral buds during the non-inductive periods (Fig. 9). In Achusa officinalls (Fig. 10) the development of lateral buds in acropetal earlier in growth but then stops till the flowering of the ***main*** shoot and becomes basipetal after that. Both the acropetal and basipetal patterns of branch emergence are, therefore, observed on the same plant (29). In Impatiens balsamina (Fig. 11) the vegetative lateral buds develop in acropetal order when plants are kept under non-inductive condition but become Floral when plants are transferred to inductive condition (30). These results, thus, demonstrate that the developmental process controls even the behaviour of lateral buds and consequently the growth pattern of the plant,

It appears that some physio-chemical changes which cause the transformation of the growing apex from the vegetative to the reproductive state are of paramount importance. The results have accumulated to show that the increased activity in the growing apex synchronizes with an increase in the concentration of ascorbic acid (AA) and a decrease in auxin. This upsurge in AA and decrease in auxin is brought about in the shoot apex much earlier in a variety subjected to long day and vernalization than under normal day and unvernalized condition (19, 20, 21). Chinoy (31) has postulated that increased production and utilization of AA enhances the production of DNA, RNA, Proteins, cell wall materials and other units of cell structure resulting in spike differentiation.

CONCLUSIONS

These correlational studies which have led to for reaching conclusions were made without any control of environment. The precise effect of individual factors of environment could not, however, be studied as it was not possible to change any factor without changing the others as well. Thus, a change in photoperiod brought about either by prolonging or curtailing the natural day light or by sowing plants on different dates resulted in concurrent changes in temperature, humidity, etc.. as well. The facilities for the control of environment, therefore, become essential in order to study precisely the effect of different levels of individual factors (keeping other factors at a constant level) on growth and development of plants, to work out more precisely their energy requirement, to assess the limits within which the photothermic concept will hold good, to study the performance of different varieties for selecting them for different regions of the country and also to study more precisely the bio-chemical and physiological changes that lead the growing apex to change from the vegetative to the reproductive state. Such facilities will also be necessary for work on endogenous rhythms, the physiology of resistance, the physiology of sex expression, and the physiology of yield. And it is in this context that I feel that a stage hos reached when such facilities should become available to us.

ACKNOWLEDGEMENTS

Finally, I wish to express my sincere appreciation to A.N. PUROHIT and PARSHOTAM KUMAR for their help in preparing this manuscript.

BIBLIOGRAPHY

I.- LANG, A., 1963.- Phytotron design criteria.- Biological principles. Proceed. Symposium on Engineering Aspects of Environment Control for Plant Growth, 1st to 5th Sept. 1962, CS1RO, Melbouerne, Australia, 5-19.

2.- EVANS, L.T., 1963.- Environmental Control or Plant Growth. L.T. , Ed., Academic Press, New-York.

3.- CHINOY, J.J., 1949.- Correlation between growth and development. Nature (London), 164, 879.

4.- CHINOY, J.J., 1949.- e.) Effect of vernalization and photoperiodic treatments on grain development in wheat. Curr. Sci., 18, 414.

5.- NANDA, K.K., and CHINOY, J.J., 1957.- Analysis of factors determining yield in crop plants. I- Varietal differences in yield of grain and straw of wheat as influenced by photoperiodic treatments. Plant Physiol., 32, 157-162.

6.- NANDA, K.K., and CHINOY, J.J., 1957.- Analysis of factors determining yield in crop plants. II- The influence of photoperiodic treatments on characters determining yield in wheat with special reference to the temperature of the ripening period.- Ibid., 32, 163-169.

7.- CHINOY, J.J., 1959.- Effect of vernalization and photoperiodic treatment on growth and development in wheat. Nature (London) 165, 882.

8.- CHINOY, J.J., and NANDA, K.K., 1951.- Effect of vernalization and photoperiodic treatments on growth and development of crop plants. Part. 1- Varietal differences in flowering of wheat and its correlation with spike growth under varying photoinductive and post-photoinductive treatments. Physiol. Plant., 4, 209-223.

9.- CHINOY, J.J., and NANDA, K.K., 1951.- Effect of vernalization and photoperiodic treatments on growth and development of crop plants.- Part. II- Vovietal differences in stem elongation and tillering of wheat and their correlation with flowering under varying photoinductive and post-photoinductive treatments. Ibid., 4, 427-436.

10.-CHINOY, J.J., and NANDA, K.K., SIROHI, G.S., and SAWHNEY, K.L., 1959.- Growth and phasic development of wheat.- I- Vegetative period and photothermic requirement. Indian Journ. Plant Physiol., 2, 29-45.

11.-NANDA, K.K., SIROHI, G.S., SAWHNEY, K.L. and CHINOY, J.J., 1959.- Growth and phasic development of wheat. II- Stem elongation, tillering and leaf production. Ibid. 2, 52-67.

12.-CHINOY, J.J., 1957.- Physiology of inheritance in crop plants. Modern developments in Plant Physiology, Report of seminar held at Botany deportment, University of Delhi, India. Ed. P. Maheshwari, 130-133.

13.-CHINOY, 1964.- Correlations in wheat as an aid to breeding for quantitative characters. Abst. 1 0th Int. Bot. Cong., 348.

14.-CHIN-OY, J.J., and NANDA, K.K., 1951.- Effect of vernalization and photoperiodic treatments on growth and development of crop plants.- III- Rate of dry matter production, net assimilation rate and water content of wheat under varying photoinductive and post-photoinductive treatments. Physiol. Plant., 4, 575-591.

15.- CHINOY, J.J. and NANDA, K.K., 1952.- Effect of vernalization and photoperiodic treatments on growth and development of crop plants. IV- Uptake of nitrogen, phosphorous and potassium by wheat plant under varying photoinductive and post-photoinductive treatments. Ibid., 5, 11-32.

16.- SIROHI, G.S., SAWHNEY, K.L., CHINOY, J.J. and NANDA, K.K., 1959.- Growth and phasic development of wheat. III- Dry matter production and water contents. Indian Jour. Plant. Physiol., 2, 83-103.

17.- SAWHNEY, K.L., CHINOY, J.J., NANDA, K.K. and SIROHI, G.S., 1959.- Growth and phasic development of wheat. IV- Net assimilation rate and uptake of mineral nutrients. Ibid., 2, 116-131.

18.- NANDA, K.K., CHINOY, J.J. and SAWHNEY, K.L., 1961.- Growth and phasic development of wheat. V- Distribution of Dry matter and some nutrient elements between stem and leaf. Ibid., 4, 112-121.

19.- GARG, O.P., 1960.- A morpho-physiological studies of the growing apex with special reference to its influence upon growth and development of some crop plants. Thesis submitted to the University of Delhi for the degree of Doctor of Philosophy.

20.- CHINOY, J.J. and GARG, O.P., 1964.- Growth and Morphogenesis of wheat as influenced by vernalization and photoperiod. Abst. 10 th. Int. Bor. Cong., 351.

21.- TAYAL, M.S., 1965.- A morpho-physiological study of the growing apex with special reference to its influence on growth and development of some millets. Thesis submitted to the University of Agra for the degree of Doctor of Philosophy.

22.- CHINOY, J.J., 1956.- Determination of photoperiodic and vernalization quanta for the vegetative period of wheat. Physiol. Plant., 9, 1-18.

23.- CHINOY, J.J., 1964.- Photothermic quantum as the basis of physiological classification of wheat (Tax). Abst. of papers 10th int. Cong., 350.

24.- NANDA, K.K., 1965.- Growth pattern of some millets and its correlation with flowering as influenced by the time of sowing. (Unpublished manuscript).

25.- NANDA, K.K., 1958.- Effect of photoperiod on stem elongation and lateral bud development in Panicum miliaceum and its correlation with Flowering. Phyton., 10 (1), 7-16.

26.- NANDA, K.K., 1961.- Some observations on the emergence, growth and flowering of branches in Popover rhoecis L., Ibid., 16 (1), 27-43.

27.- NANDA, K.K., 1962.- The emergence and development of branches in Crotalaria junceaand their relationship to flower/ing. Amer. Jour. Bot., 49, 334-341,

28.- NANDA, K.K., 1962.- Some observations on growth, branching behaviour and flowering of Teak (Tectona grand's, L.F.) in relation to light. Indian Forester, 88 (3), 207-218.

29.- DHANRAJ, 5., 1964.- Studies on lateral bud development in some horticultural plants and its relationship with flowering. Thesis submitted to Panjab University for the Degree of Master of Science (Honours School).

30.- KUMAR, P., 1964.- Photoperiodic responses of Impatiens balsamina and Iberis amara. - Thesis submitted to the Panjob University for the Degree of Master of Science (Honours School).

31.- CHINOY, J.J., 1962.- Formation and Utilization of ascorbic acid in the shoot apex of wheat as factors of growth and development. Indian Jour. Plant PhysioL , 172-201.

DISCUSSION

Lang.-Dr Nanda's paper is open to questions and comments.

de LINT .-I'd like to ask, I didn't quite catch the meaning of your formula there. At what time can you already determine what finally happens with it ?

Nanda.- The formula enables us to work out the energy requirement of a plant. The sum of the doily photoperiod from the data of sowing till anthesis is multiplied with the sum of the daily mean temperature during the same period. In this formula p stands for the mean daily photoperiod, t for the mean daily temperature and V For the period that elapses from sowing to anthesis.

de Lint.-So that means you hove to go through one complete cycle first and then you can use it for determing the time that it will take to flower.

Nanda.- Yes, we hove to determine the photothermic quantum first.

Lang.- It seems to me, of course, that the relation between the reproductive development and the vegetative one is something which is generally recognized and the big question there is only : k this a genuine course of relationship or is it a co-relation relationship ? But on the other hand, I'm afraid if we go into a discussion of the scientific aspects of any papers here they are detailed discussions and we will take away the prerogatives of the International Botanical Congress, which we all have to attend still, so I suggest we dont do that. One point which occurs to me in this connection again is : When do we need a phytotron and when do we need a couple of well controlled commercial growth rooms or self made growth rooms ? If you depend, from what you have said, and I don't feel that you are really absolutely dependent upon a medium size to a larger size phytotron, but very much of what you intend to do could be accomplished with a less elaborate facility. I'm not saying this at all to say that there is no need for a phytotron in India, naturally I'm sure that there is one, but still this brings up the point also touched upon several times in our discussions that we should really first have a pretty good idea of the type of problems we want to work on and, with this basis, decide what type of facility is required. Are there any further comments in connection with this aspect of the problem or in the general context of all the three papers we have heard, particularly the two ?

Wassink.-My comment was more particularly related to you last comment, that we should design our phytotrons according to the problems we have to go in for. Surely that is sound, but on the other hand, building with chambers costs something in the order one million Dutch guiders and I think we could hardly claim to set up that for one specific type of research unl-ess you consider this type as very flexible and very *ex*pensive.

Nanda.- It was not possible within the short time allotted to the papers to elaborate all the problems that will be taken up in the phytotron. I described some of the problems that we had been working with, I agree that some of these problems can be worked even with less elaborate facility but there are somequestions which certainly require elaborate control of temperature, light and humidity etc...

Lang.-I was trying to say that one common denominator of the three papers we have been heoring this morning is this question of, to what extent and how can phytotrons help us in our more practical problems. Dr Nanda's call in addition to its fundamental or theoretical aspects, is also an eminently practical one, for I suppose you would like to determine exactly which varieties of a crop plant are suited for the different parts of your country, and this naturally a problem which is present in many other countries. The same question has also been posed for discussion by a number of contributors who have submitted specific ideas which might be taken up here.

0

00

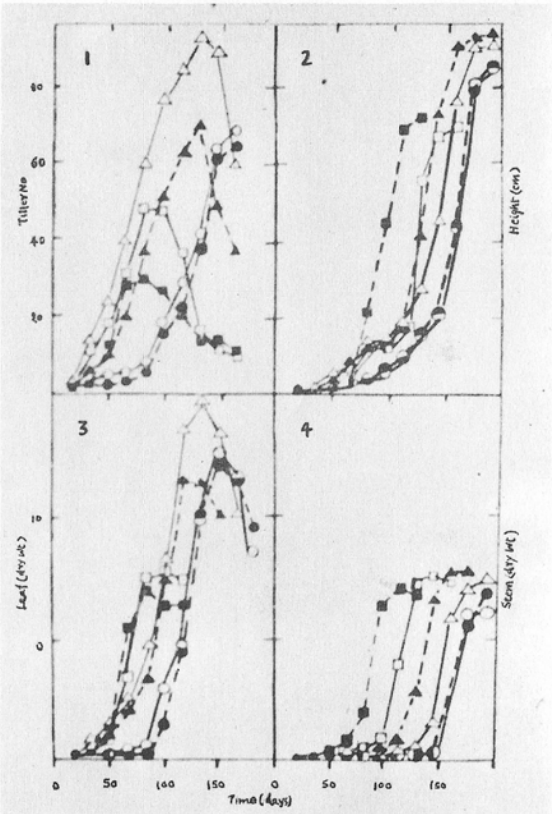


Fig. 1 .- Graphs of (1) tiller production ; (2) height ; (3) leaf dry weight ; (4) stem dry weight of Triticum aestivum var. Cambridge Rivett under six vernalization and photoperiodic treatments.

□ , Long day, unvernalized plants ;
■ , Long day, vernalized plant ;
△ , Normal day, unvernalized plants ;
▲ , Normal day vernalized plants ;
○ , Short day univernalized plants ;
● , Short day, vernalized plants.
Data from Chinoy (7).

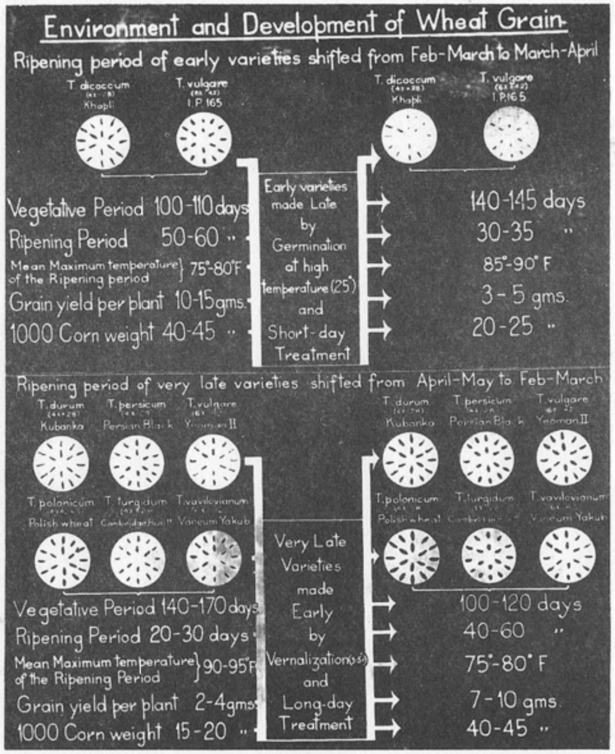


Fig. 2 .- Changes brought about in the grain yield per plant and the thousand grain weight when early varieties are made late by germinating them at high temperature and short day treatment and late varieties are made early by vernalization and long day treatment. Data from Chinoy -(4)-.

SUGGESTIONS POUR UNE COOPERATION AVEC L'APPUI DE L'UNESCO

by

M.M. FRANZLE and WALTER.

CHOUARD .-I think to begin, the best thing would be to know what Dr FRANZLE, on behalf of UNESCO, is prepared to soy to us. It should be a good beginning for the discussion.

FRANZLE .- Mr Chairman, Ladies and Gentlemen : First of all, I should like to thank you most heartily for the possibility of getting such a good insight into your manifols activities and great many problems you are ail together working on. I would like to thank you for two reasons : first of all as representative of UNESCO and secondly, in my own personal capacity as a geographer who is very much interested in getting a genetic insight into the reasons of spatial distribution of phenomena. UNESCO, whose foremost task is the promotion of science, education and culture all over the world, is very much interested in phytotronics as a new method of ecological, or eco-physiological research, and is willing to lend its prestige and also financiol support to your activities.

A great deal of the discussion here was devoted to the problem of standardization. This is indeed a very difficult and important problem. On the one hand, we all agree that for the sake of comparability, standardization is more or less urgently required. On the other hand, it is a well-known fact, that only from the mutual competition of various methods it is possible to find the best way ahead in science. Let me please remind you in this respect of the variety of methods that were hitherto developed in soil science for determining the exchange capacity d thesoil of the various constituents of soil organic matter. I think therefore, that at the present state of development of you methods, standardization of basic installations may be desirable. Beyond this, however, there should be the freedom of devoting appropriate means to each subject.

To promote this discussion about necessary basic standards, and the optimum method applicable, UNESCO proposes firstly a kind of Phytotronics Newsletter ; It could be the first platform of discussion your specific problems and the various methods to adopt. We have analogous UNESCO-sponsored newsletters which have proved very useful. I could cite the Soil Biology Newsletter as an example.

Another point UNESCO asks you to think over,is the question of whether post-graduate training courses in the field of phytotronics and their monifols possibilities of application should be started. These post-graduate training courses should enable staff members of universities or state institutions from all countries over the world to get a training in the methods and application of phytotronics or phytotrons.

In order to give you a better insight into what I mean, I should like to read some passages of a document which was prepared recently on behalf of the next International Soil Science Congress in Bucharest. "We have at present two post-graduate training courses in the field of soil science. They serve the training of staff, members of universities and scientific institutions by giving them the opportunity to strengthen their research competence and to introduce a strong laboratory orientation to their teaching. The first one on pedology and soil cartography is held at the University of Ghent in Belgium. Its purpose is the training in the fields of soil classification, soil survey and related basic sciences, interpretation of soil survey dots for practical purposes, organization of soil services adapted to local conditions and extension of soil data to farmers, foresters, engineers and technical institutions. This course has a duration of nine months and is given every year from 15 October to 15 July at the Geological Institute at Ghent. It is open to all students having already obtained a degree in soil science and any related fields such as geology, agriculture, forestry, ecology, etc... Participants who are successful in the final examination of this course obtain a certificate in soil science equivalent to a "Master's degree". A second international course of soil science and plant biology is going to be held by the end of this year at the Universities of Seville and Granada. This course will be held under the patronage of the Institute de Cultura Hisph nice de Madrid, the Cons·* Superior de Investigaclones Cientificos and of UNESCO. It will begin on 2 November and will end on 31 May 1965. The main topic of this course is the study of the plant soil relationships and their practical use for the advancement of agriculture".

Let me know come to an end with the statement that UNESCO is a well very much interested in the continuation of such little expert meetings, these symposium, os those held in Australia, in France, and the present one.

CHOUARD .- I think Dr FRANZLE , when you are speaking about training courses, (about) phytotronics, at the very beginning, what you mean exactly is especially for the developing countries, this training in what could be called environmental physiology, which is a part of physiology which is directly in connection with the techniques of agriculture and which requires a good knowledge of the different influences of different factors of the environment and how it is possible to control, more or less, simrly or more accurately this phenomenon. I think it is your idea. It is not of all intended to prepare now persons to have very complicated phytotrons in the developing countries. Maybe in the next century, but not now. And certainly, for this physiology or environmental physiology, which is one of the very important things for teaching. Some place like more or less complete Phytotron are the best place for this training.

FRANZLE .- I originally did not think of such a differentiation between young scientists coming from developing countries and those who come from more developed countries already, since phytotronics as o new method of research is so comparatively young, it would be equally good for a lot of scholars from the developed countries to be trained therein.

CHOUARD I think now we hove to discuss two proposals given by Dr FRANZLE .The first is what do you think of the idea to establish some kind of connection by this newsletter with the help of UNESCO from the financial point of view and probably some., ,

KOLLER .-I would welcome two kinds of news in this newsletter : one of them would be technical news about developments and new ideas, gadgets and so on ; the other one would be to concentrate on one place abstracts of papers of works which have to do specifically with phytotrons. This would supply, I think, in a condensed version, what phytotrons actually have achieved because some people seem to think that nothing is happening in phytotrons and things disappear in various journals, I mean just quite important iournals and the results should appear in scientific journals, but the abstracts should be concentrated in one place and sent to persons who are working in phytotrons specifically so they would at least know where to look up the full papers and secondly to provide an answer what phytotrons can do, in general. These are two things I would like to see in a newsletter like that : keeping up with technical progress and with work that has been done.

GALUN .-Maybe one can interest commercial companies to advertise and describe charts and gadgets and devices which can be helpful in the phytotron, describing all technical details with them so that people interested in this newspaper will also be informed of developments in instruments or in technique. An example : light sources by Philips Company. They may give the whole list of light sources with the spectrum, intensity, prices, and how, if they were I think it's very important. Many people are on the staff of small control chambers and they hove to go into research to look for information in this respect and this is important.

KOLLER .'But would UNESCO agree to have semi-commercial, I mean this is advertising more or less, although it's technical.

WASSINK .- I certainly would strongly welcome this abstracting. I have a feeling, however, its practically very difficult to realize. First of all, who makes the abstracts, who looks them up 1 This is quite a business. I think, I wonder wheter the organization of Biological Abstracts, for instance, would be a means of providing this. If you want to set up some abstracting service this is quite a business.

KOLLER .- No, what I mean is that members of this group, provide their own abstracts or summaries or even a short summary of technical papers which they send in as annual reports. We send in annual reports every year and some of these we would like to see the summary published as a short mate to keep people informed of what's happening.

BOGUSLAVSKY .- in our stage of work, of research, it is very important to have information. Therefore, I agree that one part *of* the news shall have information and indeed not be on a commercial basis ; It can be an information only. I think that is very important. And the other problem of abstracts you propose from publications, I think this problem is only to make or to realise with "autoreferat" and I think who is interested that his work is known that the can given an autoferat.

FRANKEL .- I think we all seem to agree and time is going on, if it is helpful to you, I should like to move that this group of phytotronic workers welcomes and supports the suggestion that UNESCO be asked to institute and support a phytotronics newsletter containing both technical and scientific auto abstracts.

CHOUARD .-So that, at the present time we have probably not too much time for a strong discussion, *but* just to adopt or reject the principle, so that the principle as proposed by Dr FRANZLE and supported by Dr FRANKEL, perhaps Dr SALISBURY has something else to say.

SALISBURY .- I was just going to say that I didn't see any reason why there should not be regular commercial advertisements. Now there may be reasons that I do not understand but this could probably support the journal and we could welcome a place where we vould see these things.

CliOUARD . - Yes, I agree with your proposal. I think this question of advertisement, commercial or not commercial, is something important but which may be decided further when we shall be just before the work to be done, but For the principle, do you agree ? I think nobody is against. But now, Dr FRANZLE, if we agree to the principle, have you some idea of how to say that, en Francais : les "voles et moyens", how to begin the job ? Is this necessary to have some persons who should be in charge at the beginning, to be in contact whith you, Dr WALTER or other?

FRANZLE .- The informations must come from your side, of course. I would suggest to form a small group of people who are in charge of the work from your side.

CHOUARD .- Who is interested ? Just for the beginning to have some contact with UNESCO about the establishment of this newsletter. We adopt the principle but with the principle alone we have nothing. It worsts some persons who are in charge and to have these contacts and to achieve this project, it can arrive.

BOGUSLAVSKY I have a proposition, Monsieur CHOUARD .

CHOUARD .- Alone is nothing, absolutely nothing. But certainly, since I om in Paris *and* UNESCO is in Paris, myself and my co-workers, good friends who are in Paris, are certainly immediately designated, not by the policy, but by the situations that they ore living in Paris and in the some place as UNESCO. But some others are necessary, maybe by correspondence, maybe sometimes by short meetings that UNESCO will promote, but who will be interested in helping us at the beginning ? (Different names : LANG, SALISBURY, BOGUSLAVSKY, KOLLER, EVANS, WASSIN K , GAA SRA).

0
00

CHOUARD .- What is your discussion about the second proposal the training courses on environmental physiology and on phytotrons and phytotronics ?

FRANKEL .- I feel that in view of the complexity of the novelty of the problem, the educational requirements should be higher than the *one* that Dr FRANZLE has given us as needed for the soil science one. I **would have** thought that a Ph.D. or its equivalent, meaning some years of post-graduate research, would be essential. And secondly, I wonder what the duration of the course would be. 1 think it should be a fairly extensive course. I agree entirely with you that it should include a course in experimental biology, plant physiology, ecology and probably some genetics.

CHOUARD think that this proposal is not for next year, but For several years, we have time before us.

BOGUSLAVSKY have the idea that a time From 3 months perhaps because less than 3 months you hove not sufficient knowledge of the construction of a phytotron. You must see and have a well when you will see and practice in work of phytotron and it will have a theoretical part and a practice part **in** this course. And then you must have two or three months.

CHOUARD .- I think we require more information about the uses of UNESCO in these training courses, because someone like Dr FRANKEL and myself partly, and several others we have the use at the present time of several people coming from different countries -you have in Canberra, r think- but they spend always at feast 3 or 6 months and Frequently more in the phytotron to work and to learn. I do not know if this has something to do with the training courses of UNESCO but perhaps Dr WALTER was asking to explain something more.

WALTER .- I would like to point out that the most appropriate duration of post-graduate training courses, especially if organized at existing institutions in developed countries, should be 9 months. With shorter courses experience showed that the students needed too much time to adjust and that it took too long to equilibrate differences in bockgroind. benefits hence were limited. Furthermore, 9 month programmes *are* better suited to the annual schedule of the various university-type sponsoring institutions, a matter, however, not applying to the CNRS. As regards the first pOssible dote for introducing a post-graduate training course in phytotronics, budgetary reasons prevent UNESCO from sponsoring one before 1967/673. Since, however, negotiations between the sponsoring institutions and their government authorities also normally last at least 2 years, this delay cannot be considered a primary obstacle.

0
00

SUGGESTIONS RECUES POUR LES DISCUSSIONS

Avant le debut de la Table Ronde, plusieurs specialistes, absents aux seances, ont presence par ecrit des suggestions qui n'ant pu titre discutees par manque de temps. Nes sont reproduites ci-apres pour servir de sujet de meditation;

I.- CHAMBERS VERSUS ROOMS (H.J. KETELLAPPER).
2.- MICROCLIMATOLOGY (H.J. KETELLAPER)
3.- SOIL TEMPERATURE (H.J. KETELLAPER)
4.- EFFECT OF AGE AND STAGE OF DEVELOPMENT ON THE RATE OH PHOTOSYNTHESE (P.M. CARTWRIGHT).
5.- LIGHT SOURCE (H.J. KETELLAPER)
6.- LIGHT INTENSITY AND QUALITY EFFECTS ON PLANT (F.P. ZSCHEILE)
7.- PHYTOTRONICS OF WOODY SPECIES : DENDROTRO(S.D. RICHARDSON)
8.- REGIONAL LARGE PHYTOTRON COMBINED WITH LOCAL SMALL FACILITIES (11 .J . KETELLAPER).

⁂

I- CHAMBERS VERSUS ROOMS

by H.J. KETELLAPER, Division of Biology, California institute of Technology,
Pasadena, California,USA.

The phytotron, as an instrument for research, suffers from the same disadvantages as any any instruments, namely that it has limitations of function. if the job changes one needs to redesign the instrument or buy another. Therefore, the design of a phytotron must be flexible, adaptable. Actual experimental arrangements, such as rooms, cabinets, should not be pars of the structure of the building.

This may be important when looking at the problem rooms versus cabinets. Presumably cabinets offer the greater flexibility. However, one must have provision for larger areas for use in studies with populations. This is must unless one can show that the variation between cabinets is equal to or smaller than that within a room. Even then the possibility and value of statistical treatment may be affected by breakdowns or abnormalities in one or a few cabinets. So, I believe that for such kind of studies rooms are a must, giving a large surface area. Furthermore, according to Kalbfleisch (Melbourne Symposium, 1962) optimal design of a light panel can only be obtained from o panel of 8 x 8 ft, used to illuminate a 7 x 7 ft area. This one would call a room. Such rooms, or multiples of 11 could still be designed as non structural units with hung light panels.

o o

2.- MICROCLIMATOLOGY

by H.J. KETELLAPER, Division of Biology, California Institute of Technology,
Pasadena, California, USA.

So far very little has been done by nature of actually determining the climatic conditions of the plant in the phytotron. We compare environments by means of air temperature recorded in some more or less appropriate way and assume that plant temperature is related to the environmental variation in some simple manner. This is not necessarily true and actual measurements tend to leave the observer quite shocked. He is surprised at the values which are much different from those expected and which vary in a complex manner with the environmental variables. Moreover, the values found are often much less uniform than was hoped.

In order to obtain a reasonably valid relation between field conditions and phytotron, microclimatological data are a must for both environments. Moreover, unless we know what actual temperatures of the plants are we will not be able to obtain the most efficient design of our facility with respect to type of air flow, rate of flow etc... It appears, for example, that for temperature uniformity and lack of gradients with plants in our units, one must rely heavily on turbulence, rather than on mass flow. We found that in experiments with controlled soil as well as air temperature the gradient between soil temperature and air temperature was shortened to about 1/4 inch by increasing the air turbulence by means of an oscillating fan. This agrees with Joffe's observations.

o o

3- SOIL TEMPERATURE

by H.J. KETELLAPPER, Division of Biology, California Institute of Technology,
Pasadena, California, USA.

It is now well established that soil temperature affects the growth of many plants. Good evidence is available from studies with grasses and conifers in the Earhart Plant Research Laboratory. In the cases of some grasses soil temperature appears to be more important than air temperature.

The effect of soil temperature occurs during germination and early growth nearly always. It affects the establishment of plants after transplanting tremendously. It may influence vegetative growth of well-grown plants with extensive root system. Soil temperature is important for the onset of summer dormancy in grasses. Thus soil temperature is an environmental factor which has to be reckoned with. In most cases the soil-temperature versus growth relationship does not show a very sharp optimum. Generally there is a plateau with a range of 10 to 15°C. where soil temperature has little effect.

In most phytatrons soil temperature is an uncontrolled variable. It is related in some unknown manner to air temperature. Where the changes in air temperature are sudded in phytorrons, the changes in soil temperature are slow depending on soil mass, moisture content etc... Particularly when ***one*** deals with daily temperature changes in the air, soil temperature is an unknown, complicated variable.

The variation in soil temperature is further aggravated by watering procedures. Watering changes the soil temperature immediately to that of the water or nutrient solution, from which it then has to adopt itself again to the temperature of the environment. Clearly temperature of the water and time of watering con entirely upset the soil temperature regime and make its daily march exceedingly unpredictable, variable and unnatural.

Therefore a case can be made for a more careful control of the temperature of the root environment than has been practiced so far. Alternatively, one can study the effect of soil temperature, if any, record the daily march of soil temperature in our various experiments and try to allow for soil temperature effects in our interpretation. This may be rather difficult, but probably many experiments can be organized in such a way that.the effects of soil temperature can be neglected, provided soil temperature has been studied first. However when extreme air temperatures, either warm or cold, are involved, soil temperature has to be reckoned with. Whatever is extreme for soil temperature or for air temperature is entirely dependent an plants species, but probably any soil temperatures below 10°C. or above 30°C. should be suspect.

* * *

4- EFFECT OF AGE AND STAGE OF DEVELOPMENT ON THE RATE OF PHOTOSYNTHESIS

by P.M. CARTWRIGHT, Depart, of Agricultural Botany, University of Reading.

Apart from fluctuations due to climatic factors, the net assimilation rate of a crop tends to decrease with time. This trend has been confirmed by growth analysis experiments in controlled environment chambers (Thorne, 1960). These experiments have shown that the decrease is associated with shading of the lower leaves as the leaf area index increases and with a decrease in the proportion of photosynthetic to respiring tissue (as shown by the Leaf area ratio). as the plant ages. Changes in the photosynthetic efficiency of the leaves probably also occur, but these cannot be demonstrated with the growth analysis technique which measures average assimilation for all the leaves.

A further investigation of the problem would entail the measurement of the photosynthesis of the individual leaves and plants both in the field and in a constant environment, where effects due to fluctuations in climatic factors would be eliminated. I would be very interested to hear about any such experiments which have been carried out in controlled environments.

* * *

5- LIGHT SOURCE

by H.J. KETELLAPER, Division of Biology, California Institute of Technology,
Pasadena, California,USA.

The old argument of sunlight versus artificial light is still with us. It seems, though, that where critical conditioning is required natural light is out. Sun light is such a variable itself, that temperature control, for example, is not terribly critical any more. Experiments done at different times of the year give different results due to differences in light quality and quantity. During periods of very low light intensities (fog, overcast) one wastes time and money, because plants hardly grow. The use of supplementary light helps, but introduces a further variable.

It is possible to obtain adequate quantity, and perhaps quality, from an artificial souroe, provided one is willing to pay the cost. The intensity required varies but it should probably be at least 4000 to 5000 foot candle for range grasses. The biochemist and plants physiologist needs artificial light most of the time because reproducibility is a prime requirement. For a variety of problems in the field of physiological ecology and applied physiology probably sun light will be adequate or even desirable. Even here one should be careful, for some cases have been found where varietal or strain relationships were different in phytotron experiments carried out in winter or in summer, due to differences in light intensity.

Light technology is developing rapidly and perhaps we can obtain higher intensities more economically in the future.

0
00

6- LIGHT INTENSITY AND QUALITY EFFECTS ON PLANTS

by F.P. ZSCHEILE, Depart. Of Agronomy, University of California, Davis, California.

Most work in plant physiology has dealt with plant growth and other responses at light intensities quite low in comparison to outdoor sunlight. I suspect that many genetic differences and other responses might well be different if high intensities *were* employed. The some may also be true in some cases for quality effects where sunlight r&ill be compared to fluorescent light quality. To explore this possibility, we have been working for several years on the design of plant growth rooms which admit sunlight at high intensities approaching that of outdoors. Our work has been described in California Agriculture very briefly. We hope that mare complete descriptions may fallow.

0
O O

7- PHYTOTRONICS OF WOODY SPECIES : DENDROTRON

by S.D. RICHARDSON, Forest Research Institute, Roturua,New Zealand.

There are many difficulties associated with the study of mature tree physiology. While much useful work can be done with seedlings, special problems are associated with the size of a tree (as for instance water conduction, carbohydrate translocotion, flowering, etc...) and with its perennial habit.

For adequate study, a phytotron is needed in which trees can be grown at least to a height of 6 meters, and in which the environmental conditions can be varied in different parts of the tree (roots, sterns and branches). Problems associated with the design of such a phytotron are obviously considerable and it is doubtful wheter any country could afford to construct such an edifice at the present time. Discussion on the possibility of international co-operation in building a tree phytotron, (perhaps we could call it a dendrotron) would be useful, as would an analysis of the features of tree growth and development which cannot relevantly be studied on seedling material.

⁂

8- REGIONAL LARGE PHYTOTRON COMBINED WITH LOCAL SMALL FACILITIES

by H.J. KETELLAPPER, Division of Biology, California Institute of Technology
Pasadena, California, USA.

A phytotron is a complex instrument and needs competent people to direct its use. No planned installation will become reality unless at least one able individual is present who has so much enthusiasm that he is willing to sacrifice a lot of time in order to get the facility established. Perhaps the presence of such an individual should be a major factor in the decision of where to loocate a phytotron.

By definition a phytotron is a facility with a large number of conditions available simultaneously. It can only be justified if the experimental work requires such a series of conditions, or else, if a large group of research workers is present who between them require an extensive range of conditions. In other words, a phytotron must be supported by a strong research group with varied interest so that a strong research program will be going on in the phytotron.

Clearly not too many places can meet all these conditions, and few universities or research institutes are able to obtain maximal usage out of a phytotron. This automatically leads to the concept of the regional phytotron, serving the needs of a large area, such as a large country, or even o continent or sub-continent.

The question is then how to best organize such a system. Experience has led me to conclude that geographical separation between the scientists home institute and the phytotron facility make experimentation inefficient, except for a few kinds of experiments which require only infrequent attention. For most experiments it is necessary that the scientist mingle with his plants freely and frequently.

Most of is work in universities where many things have to be token care of besides experiments. Much of the research work has to be done in between lectures, laboratory classes, etc... Therefore, there is no time to waste on travelling even relatively small distances. This means that many kinds of experiments cannot be done well when ones is regular work is away from the phytotron and that much of the progress is restricted to work during summer months. Even excellent technical assistance in the phytotron will not entirely do away with the inherent inefficiency.

The solution is based on the observation that many phytotron projects eventually require a relatively small number of conditions after the direction in which to move has been discovered. Plant behaviour in these few conditions is then studied intensively. Actually it is often beneficial for the project when not too many conditions are available : the scientist does not become confused so easily. Therefore, further more detailed work can be done efficiently with a small number of cabinets, rooms, small greenhouses, depending on the nature of the project. For the establishment of the direction and to define the important conditions for Further study, experimentation in the phytotron is necessary, because it allows much faster progress.

The following situation, then, would be ideal : Full size regional phytotrons are available. They can be small in number but must be large enough to accomodate a regular research program carried on by the home institute (these regional phytotrons should be located at a sizable, act ive university or research institute) as well as provide space for guest workers from the region. There should be some guarantee that the latter have a reasonable chance to obtain space. Whenever the use of controlled environment appears to be indicated the project can be started in the phytotron in order to see whether the project will benefit by such facilities and, also, to define quickly the critical environmental conditions which are essential for further study. During this time the scientist will generally be located at the phytotron, on leave from his home institute. Once the initial approach to the problem has been completed , the scientist will return to his home institute, which, hopefully, is or can be equiped with the relatively modest facilities required. In some cases it may be necessary for a scientist to remain at the phytotron for much longer time to carry his work further. That kind of problem though should be generally a cart of the regular phytotron program. In many cases the scientist probably does not need to be stationed at the phytotron for longer than one year, often less.

It is my contention that such a large regional facility supported by local small facilities will be the optimal organization form for finantial and scientific efficiency. The regional facilities could be financed by national granting agencies, international cooperation (think of Euratom) or by grants from international organization such as UNESCO, depending on conditions an area involved.

For scientifically less developed areas such a set-up is even more essential. In this way a centre of experience with controlled environment can be established where advise and training are available. In this case also the criterion should be whether the area scientist can efficiently use a phytotron and benefit by its availability. It should be kept in mind that a phytotron is no panacea, solving all problems simply and quickly. In terms of advancing the frontiers of science a phytotron as such is just another instrument with relatively limited potential. On the other hand the control of environment for growing experimental material is indispensable, but a full phytotron is seldom the best way of solving this problem for an individual or even for many institutions on their own.

0
0 0

COMPTE-RENDU DES DISCUSSIONS

Ce compte-rendu, realise d'apres l'enregistrement sur bondes magnetiques, est un résumé regroupe par sujets, independamment de la place ou les interventions ont eu lieu au tours des deux journees de travail. II n'a pour but que de refleter les idees principales des participants oCi le lecteur pourra trouver des sujets de reflexion.

00

I- COMMENT DOIT ETRE UN PHYTOTRON

En abordant les problemes generaux et les Brands principes Ou'est-ce qu'un Phytotron et comment le realiser ? M. KRAMER pose la Aria minimum de questions suivantes auxquelles tout realisateur doit repondre avant d'entreprendre la construction :

"If you are going to build a Phytotron what are you going to build ?"

- How much of your money and space is going into naturally illuminated greeenhouse space ?
- How much of it is going into artificially illuminated plant growth chambers ?
- What size plant growth chamber you are going to use ?
- How much of the space is going to be of the walk in size of room ?
- How much of it is going to be plant growth chamber of perhaps small cabinets (for example National Institute of Agricultural Engineering) and many other question.

En essayant d'expliquer ''quel dolt etre un phytotron nouveau", it attire ('attention sur le fait que la plupart du temps un biologiste ne salt reellement pas "what he really needs when he does plan the experiment" et surtout "what he needs when he begins to plan controlled environment facilities".

M. WASSINK, en parfait accord avec M. L. EVANS, pense que "what you need depends very much on what you like to do with it". 11 lui semble que, pour autant qu'un Phytotron soil essentiellement au service de la Physiologic vegetale, it doit disposer de "some controls placed in the forms of pretty large rooms and rather quite a few instead or just one, and on the other hand have some larger cabinets of say a cubic meter of useful space¹.1 Bien entendu the flexibility of a series of cabinets is larger than that of a series of rooms". II semble, par consequent, que pour un grand laboratoire, 11 faudrait "six light rooms each at a different temperature, say 5 degree apart, and six dark rooms of the same kind". Cette disposition permet déjà de reoliser un grand nombre de variations d'intensite lumineuse, de duree d'eclairage et de combinaisons de temperature jour-null. Seulement, en plus "it will be extremely useful to have some specimens of the middle size and a number of specimens of the small size as well". Le nombre, la forme et la dimension de ces petits cabinets peuvent etre aussi variables que n'importe quel appareil de laboratoire, p. ex. un Warburg. Ce sont la les regles qui devraient servir de base a is construcgion d'un phytotron.

M. KRAMER estime que, frequemment, on considere quid est indispensable que "the rooms are a part of the structure of the building" mois que, dans un grand nombre de cas, ceci nest pas indispensable cor des "prefabricated rooms simply sec upon a suitable floor and that are not a part of the structure permertraiert d'e...9-mectel. de loin lo flexibilite de ('ensemble. Dotz, dans un but de flexibilite, M. KRAMER parse ''' •eye would be many advantages in avoiding making ony of to *trol* led environment boxes or rooms on irtegral parr *of* the building. If they are simply *set* in you con pull them out ti five or ten years".

A lo suite des exposés de Mle REPP et de M. WOLFF, une tres course discussion, a iaquelle ont psis part M.M. FRA:4KEL, DOORENBOS, GAASTRA et JARVIS, a fait opparortre que, salon fa description faire par les outeurs du Rutner's Phytocyclone, c'esi plus un "very interesting gadget for researcher" (FRANKEL) qu'un Phytoiron reel.

M. LANDAU proposant de disouter "the desirability of approaching the natural condition as far as basic phytotronic arrangement" rernarqve qu'il faudrait peut etre reviser no theories. En diet, en porlant de photoperiode sans installation phytotronique, on compare en realite ''a series of fixed photoperiods with a series of gradually changing light according to the lengthening day in Spring and for o given period of time the same overage doylength with other spectral composition". On pourrait faire des essois comporatifs dans Sur. phytotron en changeant les variables. Mars it semble apparel¨re qu'il n'y a aucune information sur la reolisotion de pareilles experiences.

M. SCHWABBE rernorque que <u>('emplacement d'un phytotron</u> devroit erre choisi en fonction du but poursuivi et particulierernent des regions climatiques et principalement de la luminosite plus importance dons cer-!vines regions, Austrolie du Nord ou Sahara, ou bier de la &tree de lumiere, par exemple dons la region arctique of peut trouper des durees de fours plus longues. Peut-titre mime faudroit-il envisager un "jet plane equipped with a phytotron that could chase the sun".

M. KRAMER signole qu'aux U.S.A. la meilleure place serail ('Arizona mois, dans ce cos, il n'y a ni laboratoires, ni bibliotheque, ni Universitet a proximite, donc tout est a creer en neuf.

M. CHOUARD expose trim rapidement un pro jet imaginable d'un Phytotron au Sahara sons machine frigorifique, base sur le principe du Dr TROMBE qui utilise, pour le refroidissement la parte de calories par le rayonnement de lour comma de null, vers l'espoce celeste, a partir dune serie de trout dos par des films appropries et assez profonds oubien orient& pour que le fond soit taujours a l'ambre.

Au suiet de la <u>"flexibilite"</u> (c'est-a-dire l'ampleur des possibilitesd'emploi) M. BANERJEE (Cologne) pence que certains essais tels ('utilisation de divers types de sots naturels definis par rapport a leer poovoir de retention de (`eau ne peuvel:t trouper place dons un phytotron. Mots M. KOLLER estime qu'il seroit touiours possible de Greer "a simulated soil environment with simulated moisture stress", du moire dans cerraines iimites techniquemen' possibles.

M. COOPER rernarque que plus ou recherche un grand nombre de combinaisons dans le contrale de I 'environnement plus le nombre *de* cabinets doit etre eleve et il semblerait que le role du phytotron pourrait se limiter a avoir "some kind of large center with coarrol led cross gradients Ass ying radiation input, temperature and humidity". Ace sujet• M. SALISBURY signale Possai de M, WENT a St-Louis, base sur le principe 'cross gradient and day and night temperature" et M. KRAMER cite que le Phytotron de Madison cherche "to have some cross gradients rooms but there are very considerable difficulties in design and we don't know how successful they will prove".

MA. KRAMER et DOORENtOS remarquent que rnalheureuiement dons nos pays ocoidentaux les budgets des divers organisms gouvernernentaux sent trop rigides et empechent de realiser In flexibilite desirable, les chapitres)udgetoires pour la corsti uct ion et l'acquisition de materiel etoat differents.

Sur *i*• probleme *de la <u>"s'andordisation"</u>* des PL./rotrons (c'est a dire Pemploi universel des mimes caracteristiques culturaies), M.M. *F* ::EL, CHOUARD et SCHWABBE ont pris part a la discussion. M. KRANKEL dit "I don't think time has arrived for standardized phytotrons" car if y e encore beaucovp trap de problernes biologiques et techniques qui demeurent inconnus er or. ne peat deviner a l'avance quel choix limire de facteurs de Lenvironnement serail plus opportun 6 reter ir .

Par contre, M.M. C'-IOUARD et SCHWABBE seroient plutOt favorobles a la standardisation de certains facteurs, p. ex. qualite spectrale de la iumiere, vitesse du vent. Mais cheque Phytotron devrait avoir **Uf** specialisation fel le que les chercheurs pourraient venir travail ler dans un phytotron Out& que clans un outre sur un probleme par iculier . **Pour** ce Faire, it faudrait, bien entendu, diffuser les caracteristiques de chaque phytotron.

Une courte discussion entre M.M. LEOPOLD, MORRIS, KLUETER et LINCK sur les possibilites de simplifier le systerne de climarisetior des salles ou petits cabinets en vtilisant le mime our pour la climatisation et pour le refloidissement des Iampes a fait apparetre que cette simplification pose des problemes techniques del icars.

* *

II- TEMPERATURE DE L'AMBIANCE ET DES PLANTES

Les discussions sur la temperature ant porte sur deux points essentiels ie probleme de la temperature et le probleme de la mesure.

Au tours de la discussion ossez animee sur la temperature et l'ambiance, M. JEWISS declare :
"1 feel that too much attention has been paid to ambient temperature ... car "of course, there are interesting relationships between ambient air and that of the plant tissues but it may not be as direct and immediate as one *often* imagined".

M. SALISBURY, par contre, pense que "the plant temperature is any different from the ambient temperature and it is a tremendously important question" mail seulement dans le cos 00 l'intensite lumineuse est tres elevee. Cependant the leaf temperature is not the same as the ambient temperature".

M. HUGHES signaie qu'a Reading un groupe de chercheurs travaille sur "for-red radiation balance energy in the small cabinets and installation with integration changes".

N.B. La temperature de l'ambiance d'un local climatise Mont cello de fair a l'abri de tout rayonnernent, le prableme a ere traite a Gif-sur-Yvette en adoprant pour la conduite de la regulation, de mime que pour le contrOle, un tunnel ventile dans lequel sont places les diverses sondes. Ce micro-tunnel est constitue dune grande boite en metal chrome bien reflechissante, recouvert interieurement de plastique expanse. Un ventilareur fait passer fair de la piece a une vitesse de 3 m/sec. sur les diverses sondes.

M. BRETSCHNEIDER, en reponse a une question de M. NITSCH, donne quelques precisions sur l'alternance des temperatures qui, cornme II l'indique dans sa conference, ant lieu taus les 5 fours. Cette duree provient des recherches effectuees d Giessen et qui montrent que "a cool period of five days may have an influence on yield or otner date and therefore we take this pentode cycle through all our programs" car 5 fours ant une influence settlement pour 1/2 degre ; si on prend une duree plus grande, 10 fours p. ex., il n'apparaitra de difference que pour 1 degre. L'alternance de temperature jour-nuit est comainee avec une periodicite lournaliere de 5 'lours.

A ce sujet M. W■THON suggere ('utilisation 'Pun prograrnmateur astronomique qui permet d'adapter le cycle quotidien sans grande difficuire technique.

M. 1V1OHR estime *que* le prof:arme de rnesure "is hardly serious" ; bien entendu tout depend des pcoblemes etudies mais les interferences entre la lumiere et les variations de temperature sont fres importantes. II lui semble qu'il seroit Hes interessant d'etudier ottentivement la question if it it really reasonable to measure and to control the temperature in the air of such a chamber with a high accuracy without knowing exactly what the temperature differences are between day and night within the tissues for example".

M. KRAMER, remorquant que out of doors practically all our experiences hos been based on air temperature climatically speaking and so on pose lo question : are we going to use a new index ?"

"I would like to suggest, dit M. DIMOCK, that its most important to define how our temperatures are being measured" car "when we have light intensities of approximately 5 thousand foot candles, we find that elevations in temperature is about 3°C jump in the temperature of the leaf tissue when the lights are on over when they're off Mais qu'appelle-t-on, dans ce cat, une foible difference de temperatures ? : it terrible que 3°C est une difference appreciable surtout si Ion considere "the number of degree hours during the day period".

M. SALISBURY pence qu'avec 2000 ***fc*** dreclairoge„rname area un mouvernent d'air important, on ne peut arriver 8 avoir the air temperature fairly close to the leaf temperature" ... et qu'il y a lieu de tonic compte de la difference dons not rnesures et dans les caracteristiques des chambres condirionnees.

Pour M. JEWISS ce probleme de difference de temperatures est surtout important if you try to extrapolate natural environments and try to stimulate them in the controls". In effet, dans ce cos, interviennent les differences specifiques et d'oaciptorion des plantes b la viresse du vent. Quelques essais ***ant ete*** faits S Stanford tutce sujet.

M. MOHR estime qu'il n'y a pas de solution generale et parfoite car trop de focteurs interviennent. Neanmoins, !'utilisation de thermocouples places a I Interieur de la plante au lieu de thermametres notTnovx permettrait de maintenir "the temperature of the chamber at such a level in order to maintain the same temperature within the tissue".

Pour M. NITSCH, lo question se pose de la faion suivonte : Quelle est la temperature de lo plante et quelles tiges ou feuilles choisir pour la mesure ? II y o, en effet, de grandes differences.

M. WASSINK rappelle que la difference entre la temperature ambiante et la temperature des feuilles depend principakerrent de Is quontiie d'infra-rouge et specialement de l'infra-rouge lointain dans ies sources lumi neuses.

Pour M. LEOPOLD, la meilleure fawn d'apprecier to temperature des feuilleseSt l'emploi du radiornetre **qui** permet d'examiner routes les feuilles sans faire appel au thermocouple.

En conclusion, M. KRAMER propose, pour lo pratique, I `utilisation d'elerrients sensibles proteges pour la mesure de temperatures, sans oublier que, pour certoins trovaux ecologiques et physiologiques, it faudra tenir compte du fait que la temperature observee sera differente de In temperature des feuilles.

Et Mle REPP rappelle opportunement que lo satisfaction des besoins en eau dune plante peut faire varier la transpiration, doncla temperature des feuilles.

* * *

III- LUMIERE

Les discussions cur la lurniere ***ant*** etc tree nombreuses et tres longues, car elies out pris, en realize, presque la moitie du temps des reunions. Nous avant regroupe les diverses MIles ernises dons lee paragraphes suirants :

a) Qualit& spectrales de la lumiere.
b) Intensite lumineuse optimale pour l'eclairage artificiel.
c) Possibilites et utilites de variations de l'intensite lumineuse.
d) Mesure des niveaux d'eclairement.
e) Types de lampes is choisir : lampes if incandescence
    lampes fluorescentes
    rapport fluorescence-incandescence
    lampes 6 vapeur de rnercure
    lampes 6 xenon.
f) Reflecteurs et peinture des murs.
g) Verre et plastiques transparents - Facilites de nettoyage.

III- a) QUALITES SPECTRALES DE LA LUMIERE

M.M. GAASTRA et MOHR remarquent que la qualite spectrole des lampes vane avec les fobricants et les pays. De plus, le choix du spectre optimum dolt dependre des recherches et des orgonismes cultives (Gigue, organisme inferieur et meme especes de plantes superieures).

M. MOHR signale qu'avec un arc 6 Xenon on pout reproduire le plus exactement la lumiere soloire. En utilisant en complement des filtres Schott we approach the spectral distribution of the sun in the range between 300 and 750 millmicrons".

M. NITSCH attire ('attention sur le point suivant : Si les tubes fluorescents contiennent suffisamment de "red and for-red", it n'est peut-etre plus necessaire d'ajouter de Ia lumiere incandescence ? Et, d'ailleurs, qui connatt quel rapport fluorescence-incandescence y a-t-il lieu de maintenir dans un Phytotron ?

M. VAN de VEEN pense que, dans l'oppreciation des qualites spectrales, iI ne faut pas supprimer le proche ultra-violet qui existe dans ('emission de la majorite des lampes. A voter, d cc sujet, que "a plant that has been growing all the time in the artificial light environment will grow very well and plants coming from outside have to adapt themselves". D'ailleurs, les plantes ayant pousse sous lumiere artificielle ont quelques proprietes differentes (cuticule, pilosite, etc...).

II semble que, comme le remarque M. LEOPOLD, on ne peutseparer le probleme de la qualite du probleme de l'intensite de Ia lumiere;

M.M. MOHR *et* LEOPOLD soulignent l'interet de la communication de M. NISHIZAKI et pensent que cette methode de determination in situ de l'energie et du spectre dons les salles du phytotron est tres utile "in order to know what spectral distribution we have especially in the case when you odd incandescent light to other sources".

M. WASSINK estime qu'a l'heure actuelle aucune information serieuse ne peut etre donnee en ce qui concerne la qualite de la lumiere car "a slight difference in very specific spectral regions might cause great effect". Neonmoins, on peut actuellement to grow quite normal plants at fairly low intensities with only daylight fluorescent tubes". Cependant, rnalgre cela, M. WASSINK prefere install as high energy as we fairly can without exaggerating the ventilation requirements too much. We don't yet know what sort of spectral conditions we will have to make to achieve normal plants in our new conditions". Aussi utilise-t-il, dans son laboratoire, "80 fluorescent tubes of 120 W from something like 1 1/2 times 3 squares meters".

III- by INTENSITE LUMINEUSE OPTIMALE POUR L'ECLAIRAGE ARTIFICEL

Parmi les nombreuses remorques faites sur cette question, retenons les plus interessantes :

M. DOORENBOS signale une comparaison foite a Wageningen sur la croissance des plantes dans les memes conditions de temperature et de duree d'eclairement en serres et en sales a eclairage artificiel : "In december , the plant under fluorescent tubes grew better than in the greenhouses and the difference become less and less as the nature light intensity rose, in march the growth of the plants under the PI. 40 W tubes light was the same as under the sunlight and than in April and may the plants in the sunlight was a head". D'o0 it concl-ut que Ta croissance tout au long de i'annee dons les conditions d'eclairage artificiel se rapproche a Wageningen de cefles du moil de mars en eclairage noturei.

M. GAASTRA, ainsi que M. LEOPOLD, pensent que nous connaissons rnal les conditions optimales d'intensite lumineuse pour les plantes et it ne leur paroit pas du taut evident que la lumiere estivale soft au-dessus de l'optimum. Cela serait du" pia& ay fait que Pine des attires conditions soil˙ limitonte, par exemple : temperature, ventilation, insuffisance de nutrition ou d'arrosage. Ce point pourrait, semble-t-il, 'etre verifie dons [es phytotrons?

M. CHOUARD remarque, a ce sujet, que ce n'est pas du tout la meme chose d'essayer de reproduire exacternent les conditions naturelles que de povvoir disposer de bonnet conditions reproductibles a volonte, incle-finiment.En effet, au phytotron, sous lumiere artificiei le constante, pendant 8-12 ou 16 heures, [es resultats obtenus concernant les processus photosynthetiques sont fres differents de la nature o0 it y a variation pratiquement perpetuel-fe de l'intensite : au court d'une fournee d'ete, vers le milieu de la iournee, l'intensite lumineuse est ou moins 4

fois svperieure a celle obtenue avec les meilleurs tubes fluorescents. Mais Ta permanence et la constance du flux de ces derniers au tours de la journee font que la production de matiere seche, la photosynthese et Pellet photoperiodique sons meilleurs. Dons ce car, certaines plantes <u>(Myosurus minimus,p.ex.),ou</u> lieu de rester plontes de fours courts, deviennent indifferentes. 11 est absolument evident que Les plantes s'adaptent a 10 lumiere artificieile mais cette adaptation ne se realise que pour les ieunes feuilles, les vieilles feuilles ne changeant ni leur texture ni leurs racteres.

Ce fait est confirme par M. LEOPOLD et surtout par M. WASS1NK qui cite les travaux de M. PETERS sur ('adaptation des feuilles, probleme analogue au "old problem of the sun and shade leaves".

M. N1TSCH pose 10 question suivante a M. BRETSCHNEIDER Le cycle de 5 Tours de temperature indique dans sa conference est-il complementaire o un cycle d'eclairement variable ? Les experiences a ce sujet n'ont pas ete foites. Cependant, M. BRETSCHNEIDER a realise one experience qui semble indiquer que l'intensite lumineuse peut portiellement etre remplacee par une duree de lour plus longue, notammeni un passage de 25000 lux 0 20000 lux peut etre compense par un allongement de to duree du jour de 2 heures, croCt it conclut que : The effect of two hours longer days mode about 5.000 lux".

Ceci a ete egalement constate par M. LEOPOLD,comme on peut le voir dans fa publication de M. WENT de 1957 contenant a ce sujet de nombreuses experiences, notamment sur les tomates.

M. de LINT signale egolement un essai sur LaRue oa l'intensite lumineuse et la duree du jour se compenseraient ?mils, dons ce cos, intervient peut-etre une action de ('infra-rouge.

M. BRETSCHNEIDER pense que ces compensations sont fonction de la duree de la vegetation.

M. MOHR rappelle que les exigences des plantes sont fres variables et I' "energy requirements might be different in the relation 1 to 10 but you certainly can grow many plants with 8-10.000 lux from seed to seed",

M. LEOPOLD utilise dons son loboratoire une source lumineuse donnant 5.500 fc, si necessoire ovec filtre ; mais est-ce necessaire d'al ler si loin ?

Pour M. KOLLER, l'intensite optimale depend des plantes : ainsi, pour le Mais p. ex., on n'arrive pas a saturation, mime en plein soleil.

M. 3OGUSLAVSKY remarque que le probleme de l'intensite lumineuse est etroitement lie au probleme des mitres facteurs de croissance et du rapport existent entre chocun de cis facteurs. En effet, la nature nous donne des exemples : In the Nort states of Europe where we have a shorter vegetation but a longer day, the yield of the plants is the some as in Central Europe". Aussi, ('opinion de M. BOGUSLAVSKY sur l'intensite lumineuse et non sur to probleme du spectre de la lumiere (qui serait un probleme different) est I "Have you the plant in the same conditions as it is growing in Nature ? This is certainly very important for us because we have special plants ; and we can say under our conditions we had the dry method as in the plant in Nature and we have the ratio of grain to the vegetative part of the plant as in Nature. These indications ore for my opinion, very important to this problem. How is the ratio of light to temperature, length of day or photoperiod".

N.B.- Le maintien d'un niveau d'eciairement oussi constant que possible pose la question du vieillissement et de la TTs ; de flux, donc du changement des [ampes. Si la courbe de baisse de flux des lampes a incandescence avec Page est relativement peu importante at bien connue, cells des tubes fluorescents Pest beaucoup mains. Les courbes proposees par les fabricants soot fausses par defout et obligent l'utilisateur a un contrale permanent. A Gif-sur-Yvette, apres beaucoup de tatonnements, on a constitue des plafonds lumineux avec un melange de tubes de divers ages at elimination des tubes de 125 W. apes 4000 heures d'utilisation. Cette bacon de proceder, fastidieuse, cermet de nxiintenir un niveau d'eclairement dont la variabilite est inferieure a -1-15 %.

III- c) POSSIBILITES ET UTILITES DE VARIATIONS DE L'INTENSITE LUMINEUSE

M. DIMOCK attire ('attention sur le point suivant : When we are discussing cyclic variations between high light intensities and low light intensity, we are also discussing variations in leaf temperatures and all that implies."

1- Realisation de l'aulDe at du crepuscule

Mle REPP estime, de mime que M. BOTTLAENDER, qu'il est necessaire "to increase slowly the intensity of light and to decrease it slowly also" car, dans le cos controire, avec "sudden shocks of heat or light the chloroplasts clump together" et it lui semble que, dons un phytotron, "that shocks of light shouldn't be too strong".

M. LEOPOLD rappelle, a ce sujet, les ancient essais de M. GORDON, vers 1930, sur la periods d'induction du systerne photosynthetique qui "takes several minutes say in the range of 2 to 5 minutes for full range photosynthesis to set in".

M. DOORENBOS signale qu'on pout remplacer l'aube at le crepvscule par de nouvelles lampes "dim incandescent light and dim fluorescent light". M. DIMOCK n'en a pas entendu parlor mais M. MORRIS utilise un "dimming device on fluorescent tubes" pouvant diminuer l'intensite jusqu'o 75 % du maximum, malt it ne salt pas toutefois s'il y a en mime temps variation de la repartition spectrale.

M. KLUETER indique qu'e Beltsville les lampes fluorescentes ant des ballasts separes : they have chokes and they have capacitors and there was a small capital ballast that goes right in, with the lamp, and in this it is possible to dim the light and get the full out put to the maximum,this system is being manufactured commercially".

Mais M. MORRIS realise dans ses cabinets I' "effective dimming by turn out light on the cabinet", chacune des 58 lampes pout erre eteinte par un programtnateur en donnant une precision de plus ou mains 1 %.

M. DIMOCK suggere une rnethode simple pour faire varier l'intensite sans toutefois savoir ce que deviendra la qualite, c'est de "to merely vary the regular flow of air over the tubes so that their temperature varies".

2- Lumiere intermittente :

Mle REPP signale la possibilite de ('utilisation de la lumiere intermittente fournie par des lampes Siemens utilisees normalement pour ie balisage des aerodromes et fournissant une lumiere fres puissante.

M. BOTTLANDER indique un essai effectue avec de la lumiere intermittente a l'aide d'un disque a secteurs tournant en 2 minutes. Les plantes obtenues avaient une bien meilleure croissance et etaient bien plus co-['Drees que les remains.

Mais M. MOHR, comme cela a ere debattu a Oxford, pense que la lumiere intermittente est dangereuse car "apparently, photosynthesis and the different photomorphogenic processes have different requirements". Aussi, it ne recommande pas cela pour une installation de phytotron "before we know more about this".

M. LEOPOLD pose la question sur davantage d'avoir le "twilight effect on the morning and on the evening because you would not completely saturate your light system". Mle REPP dit que M. ZANDLER et ('Agricultural Research Institute de Vienne travaillent sur ce probleme, mois chacun d'un point de vue different : M. ZANDLER sur l'effet photoperiodique et l'Institul d'Agriculture etudie la question de la diminution des frais. M. SESTAK rappelle que ces questions ont cieja etc elaborees *en* 1956 et discutees avec l'effet Emerson.

M. DOORENBOS n'oublie pas qu'en horticulture "we are interested in optimal conditions and the fight intensity of the sun in our country in the middle of summer is too high, over the optimum". Aussi pratique-t-on le clayonnage des serres. II est, par consequent, interessant de pouvoir changer a volonte, par extinction d'une partie des lampes, comme cela est realisable au phytotron de Wageningen, l'intensite lumineuse dons les sal les scion les plantes cultivees. Cette possibilite paratt a M. LEOPOLD interessante eta retenir.

III- d) MESURE DES NIVEAUX D'ECLAIREMENT

Cette question, particulierement importante, a etc abordee a plusieurs reprises. Les plus interessantes rernarques ont ere faites par M.M. GAASTRA, KOLLER, LEOVTLD, MOHR, VAN der VEEN, WASSINK et WOLFF.

M. WASSINK estime que, pour etre valable, I I Faut executer : "our light measurement in the correct way which means that *we* should know more or less the properties of our measuring apparatus and secondly that we describe our experiments sufficiently well for somebody to repeat us".

M. MOHR complete cette idee : "Everybody con use instead of a single photo element or photomultiplifyer diffuser system is available nowadays and then he can be sure that the light which comes from angles is about measured in the same way and that can be achieved with a little bit of additional technical achievements", Mais it faudrait ajouter a cela la distribution spectrale de la lumiere a ['aide dune methode simple, par exemple en utilisant un spectrophotometre enregistreur. II propose egalement en variante de cal ibrer I a mesure *faite* avec le photo-element a l'aide d'un spectrophotometre et de donner les valeurs mesurees en unite absolue, ce qui, sans etre absolument exact, permet de se mpprocher davantage de la realite qu'une mesure sans aucun commentaire.

Comme precision pour le systeme de mesure, M. MOHR dit que tout appareil "if you just keep the upper element in the space it measures only a certain percentage of angle of 180 or 360 degrees'. Aussi ii taut ajouter a la cellule ou au photomultiplicateur un diffuseur qui peut, par exemple, etre en pyrex de facon *A* ce que the distribution of the energy will be homogeneous independently of the direction in which the light beam enters". Bien ent endu, ajoute-t-il, "you have then, of course, a certain spectra which must be calibrated a certain spectral reproduction through the diffuser system, but this spectra can be eosily determined with one calibrated wavelength and in this way one can reduce the cosign error of the whole system down to one or two per cent".

M. WASSINK complete cet exposé en rappelant le travail qui a ete realist dans son laborateire et qui donne la repartition spatiole de la lumiere avec une erreur d'environ 10 %, (Note de la redaction : fa description de cet appareil est donnee dans I'orticle suivont de l'auteur : "A spherical radiation meter for plant irradiation purposes" by E.C. WASSINK - Proceedings ist international Photobiologicol Congress, Amsterdam, 1954, pp.299-303) Neanmoins, M. WASSINK souligne y a deux points à considerer : "First what light is incident from a fiat surface and than you hove to take core of the cosign law as Dr GAASTRA said", question qui, à son avis, est plus ou mains resolve. Mois "the other thing you want to know is the incidence into a point of space which is especially reasonable if you have a sort of three-dimensional plant standing somewhere in a light field" at c'est precisement ce deuxieme point qui o ete resolu avec Peppereil decrit.

M. WOLFF signde egalement qu'un apporeil : le Spherolux, meter, est commercialise par les Ets Butner de Vienne. Appareil qui, comme le fait renorquer M. LANG, ressemble fortement d celui decri par M. WASSINK.

M. VAN der VEEN rappelle ce qui a ere dit par M. NISHIZAKY dons so conference en ce qui concerne la mesure de fa lumiere et son expression en lux et foot candle qui, pour des valeurs identiques, peut donner des resultats ties diFferents. Aussi propose-t-il "We might better give the spectral indications of the lamps used and light quality".

N.B. - Les mesures du niveou d'eclairement, a Gif-sur-Yvette, sont effectuees avec : un pyrhel,iornetre KIPP pour TeTergie solaire directe et diffuse et avec un thermopile JACOBSEN pour Peclairement des solles obscures. Un spectroradiometre ISCO permet ('analyse spectrale, in situ, dans les salles.

A noter egalement que l'ouvrage "Actinometry and atmospheric optics" Ed. Valgus, Tallinn 1968, donne la description des appareils sovietiques qui permettent de mesurer les radiations photosynthetiquement actives (FAR), mesures preconisees par A.A . NICHIPOKOVICH.

III- e) TYPES DE LAMPES A CHOISIR

Mle REPP, se bosant sur le fait que la grande majorite des scientifiques reunis sont botonistes et n'ont, par consequent, que peu de connoissances sur les lampes à utiliser, propose, pour l'avenir, de faire connaitre "what a sort of lamp is used in this or this phytotron and what lamp is may be use in divers circumstances. May be, in this way , we could do something useful for the future some technical help".

M. WASSINK ne pense pas qu'une comparaison des resultats obtenus par les physiologistes dans ('utilisation des diverses lampes soit tres interessante, comma ceci a ete constate au Colloque de Canberra, en 1962.

A ce sujet, M. GAASTRA surencherit en remarquant que, pour les plantes tout depend du probleme etudie car "many treatments are basically different in different energies and in same view spectrum distribution which we have in spectrographe distrib-ution doing so from different lamps is very reasonable for choice of different kind of sources".

M. BOGUSLAVSKY fait remarquer avec pertinence que dons le choix des qualites de la lumiere rout depend "how long you will have the plant in the chamber and how long you will make your experiments" et egalement "when you have an experiment for a short time it is possible to have one or two factors which are controlled and the other factors are constant. But when you are making experiments for food and vegetation it needs that you make a program for many factors depending from the number of chambers you have for doing it. I think that the minimum 8 or 10 chambers is necessary because you have in your system minimum 5 or 6 factors. I think that only the experiments for short time can be made in the cabinets", ceci parce qu'on ne pourra jamais rien conclure sur aucun probleme de physiologic vegetale si l'on ne possede pas des planter normales 6 croissance similaire et dienviron mame aspect que dans la nature. fans ce car, it en serait de meme, pour un Phytotron, du chats de la dimension et du nombre de pieces, routes questions qui dependent essentiellement du point sulvant "You will have experiment for short time or you will have experiments for the whole vegetation".

Mats, comma le remarque justement M. KRAMER, *ce* qui est le plus difficie c'est de pouvoir decider clairement et obiectivement "what it is and what to do. It seems simple but it is often very difficult".

M. WASSINK mppelant que nos connaissances of the reaction of a plant to an environment is still in a very primitive state, especially as far as serial variations of factors are concerned" propose d'adopter "a certain technically manageable illumination which is reasonably satisfactory for average purposes and start our investigation with that". **Il** suggere 'to adopt the same type of lamps, but lust each for ourselves adapt a certain type of lamp and just start making light intensity series or whatever you like'.

M. fv1OHR pense que an unification of light sources would be highly desirable and on the other hand a certain unification how to measure light intensity would be desirable also" ceci dans le but de comparer les resuitats de divers laboratoires. Afin que les essais soient reproductibles, if four une bonne description des methodes d'eclairage uHlisees et egalement de l'oppareil de mesure car les valeurs seront differentes avec les elements sensibles utilises : photoelement ou thermopile, p. ex.

M. LANG ne pense pas comme M. MOHR et estime *que* les installations "depend on what we wont to do : if we want to study specifically light adaptation, spectral heat, etc..., this is a different condition but if we want to do some other photoperiodic experiments all we need to do is to grow the plant under standardized condit ions" .

M. SALISBURY est du mieme avis que M. LANG, tout en signalant que "surely we could make every effort to make the best measurement so we can define our conditions but to try to have uniform conditions every where it seems a little bit early to be approaching that sort of thing".

In conclusion de lo discussion, M. LEOPOLD pense que "the objective of high intensity is sometimes co; really all-pervading requirement that is the quantity of light is still really an uncertain issue, and how serious it is to have high, medium or low intensities is not really clear".

The quality of light remains an empirical decision : you light your lamps and you hope that the qualit ies of light are giving you the response that you can put up with".

Aussi, M. LEOPOLD suggere que pour route nouvelle construction de phytotron ii faut
- faire un essai en petit, constater une bonne croissance, puis installer les men leures lompes.

1- Lampes 6 incandescence :

La discussion concernant les diverses lompes utilisables, proposee par M. LEOPOLD, est engagee par M. LEWITT *qui* signale qu'avec des ''incandescent spot lamps placed six inches apart, it is possible to get the full intensity of sunlight and foot candles were a little higher. The wavelength distribution was supposed to be pretty near that of sunlight".

M. CHOUAR❑ pose is question de l'utilisation des "iodine lamps" qui sort a incandescence mats de 10.000 heures de duree de vie et qui sant survoltees, donc avec une qualite de lurniere rnelleure que ('incandescence ordinaire. Ces lampes ant beaucoup d'infrarouge que lion peut partielfement eliminer avec is &ran &eau et disposer ainsi de 50 a 80.000 lux, intensite parfait necessaire et relativement ban maiche sans installation spechile. M. SALISBURY precise que lliode sert dare ces lampes uniquement comme regenerateur du tungstene du filament qui normalement vient se precipiter sur les parois de lo lampe ; la courbe speqtrale est Celle dune lampe incandescence normal e.

M. SALISBURY indique aussi ('utilisation possible de "quartzline incandescent lamp *of* five hundred watts" : en placant 24 tubes de la dimension d'un crayon a 1 inch de distance en 2 rangees, on obtient une intensite lumineuse tres elevee. II faut utiliser un filtre 6 eau pour evocuer la chaleur excessive et diminuer une certaine quantity d'infra-rouge.

M. KLUETER rappelle que toutes les latrines a incandescence peuvent etre sous ou survoltees ; malheureusement, cela se repercute obligatoirement sur lour duree de vie ; p. ex. photoflood ou flash bulb dont on peut augmenter la luminosite de dix fois et plus, mail dont, dans ce cas, on diminue de 1.000 fois et plus la- duree de vie.

2- Laryes fluorescentes :

M. LEOPOLD pose lo question t Y a-t-il eu des comparaisons faites entre lampes fluorescentes corn-mercialisees et notamment les dernieres noes : Gro-Lux (Sylvania) ou Plant-Gro (Westinghouse) qui ont approximativement le meme spectre d'emission ?

M. NITSCH indique *que* "day light tubes give better growth than the Gro-Lux ". Ceci semble, d'apres M. LEOPOLD, etre d6 a *ce* oue "the Gro-Lux has a very poor ratio of red and for red in the spectrum". ?viais M. GAASTRA trouve que per unit of light emission the Gro-Lux has twice os much red as the sunlight".

N.B.- OSRAM fabrique depuis 1968 des tubes fluorescents appeles "FLUORA" qui emettent essentiellement des lumieres bleue, violette, orangee et rouge. Ce spectre d'emission (trees pauvre dons le vert) recouvre bien le spectre d'action photosynthetique et, ae ce fait, ces tubes presentent un interet certain pour la croissonce des plontes.

M. SALISBURY signale qu'avec les tubes Phytor "high plants grow very fine". M. BOULLENNE, qui a mis au point *ces* tubes avec les ACEC en Belgique dit : "We succeeded to have a mixture of different wavelengths by which we had the same result in the growing of plants, the dry weight, the color, the length of sterns, the flower, the type of Flowering at the same time and with the same dry weight in the green house and in the cabinets. We found out that with 4 tubes of different wavelengths we have a mixture which is very successful. They succeeded in the factory to put the wavelength of those four tubes into one tube we call Phytor". II fait remarquer egolernent qu'a l'epoque on se preocupait moins des radiations rouges que l'on a forternent reduites mais, avec nos connaissances actuelles, "perhaps we shall try to introduce it".

M. WASSINK, precisement, pense que, pour divers tubes, le spectre est suffisomment correct pour permettre une forte absorption pigmentaire photosynthetique. Par contle, morphogenetiquement, "which plays with the pigment phytochrom which presumably is present in very low concentration we will have very sharp bends" et it semble que "certain tubes having some of this near infra-red (or far red) ore much better than some which have none, or much less" et c'est de cola qu'il Faut surtout tenir compre dans le choix *des* tubes.

Sur une question de M. LEOPOLD "If any one has hod experience mixing bulb types lamps to enhance the red end of the spectrum ?" M. DOORENBOS precise que "it is not red, actually TL 55 *Ourniere du* jour) is bluish but it has this infra red in it". II signale egalement que "we find that the effect of fluorescent light depends on the species of the plant" et it lui semble, 6 la suite de plusieurs experiences avec et sans incandescence en complement de tubes fluorescents, que souvent "it is just an absolute quantity of infra red and not the percentage which is important. Of course, the percentage remains the same, the absolute quantity rises including more fluorescent tubes". Avec certains tubes, comme p. ex_ "the color 29 (Blanc Super) which has a lot of red but no tail to it in the infra-red there ore some plants that don't gcow very well". Aussi, octuellement, "I have substituted part of these tubes 29 for the color 55 which is the one that has thin stripes, that has most infra-red in it and than that has given quite an improvement in those plants that did not grow before".

N.B.- L'utilisation des tubes fluorescents "Lumiere du jour" de 125 W. a toujours donne d'exceflents resultants a Gif-sur-Yvette. Neanmoins, le spectre emit etait souvent modifie avec le vieillissement. Ce fait est sans dovte du au melange de poudre utilise dans la fabrication en quantite peu importante. A partir d'aiciiit 1968, de nouveaux tubes fluorescents 'Blanc Super" de 80 W on' ete utilises pour raison d'economie. Ce changement provoque que quelques variations quantitatives dans le developpement de quelques plantes, notamment chez Anagollis arvensis, en ollongeant la dyree d'induction florale. Par contre, aucun chongement qualitatif n'a ete observe sur les quelques quarante especes de plantes en etude depuis plusieurs annees.

M. WASSINK, au sujet de la qualite des lampes, rernarque qu'avec des lampes "day light fluorescent tube only" it a obtenu de tres bons resultats. Or, on parle de plus en plus d'ajouter de ('incandescence. Peutetre est-ce indispensable, mais it semble que tout depend de l'intensite lumineuse et les conclusions des essais a foible intensite ne doivent pas etre extrapoles aux fortes intensites. Comme le souligne M. MOHR, it foot un bon equilibre entre le spectre visible, le proche (red) et le lointain infra-rouge (far red) durant toute la duree des experiences.

En ce qui concerne les reflecteurs separes ou incorpores 8 l'interieur des tubes, M. MORRIS, qui les a compares, signale : "We find that, in our cabinets with the common reflector over the top *of* the bank, we have greater out put than with reflectorized tubes". La meme observation a d'ailleurs *ere* foite au Phytotron de Gif, au tours des essais preliminaires d'eclairage.

N.B.- Les mesures comparatives faites a Gif-sur-Yvette ont permit de constater qu'un tube fluorescent recouvert d un reflecteur parabolique en aluminium poli eclaire plus que tout autre systerne de reflection de la lumiere

- Tube fluorescent sans aucun reflecteur - 900 lux (100 %).
- Tube fluorescent avec reflecteur incorpore - 1680 lux (186 'Q.
- Tube fluorescent avec reflecteur et reflecteur aluminium poli - 2460 lux (273 %).
- Tube fluorescent sans reflecteur incorpore moms avec reflecteur aluminium poli - 2600 lux (288 %).

M. VAN de VEEN estime que ces resultats proviennent de *ce* que "a lot of dust coming down on the upper part of the tube and so when you have a good reflector and dust free tubes, then you can better have a reflector".

M. KLUETER est *en* parfait accord avec M. MORRIS sur l'inutilite des reflecteurs incorpores dans les cabinets. II pense, en plus, que "the out put goes down on reflectors a little bit faster". M. LEOPOLD a egalement fait la meme observation.

3- Rapport fluorescence - incandescence :

M. LEOPOLD propose une courte discussion sur "the ratio of fluorescent to tungsten lights in the conventional light bank system". A combien ce rapport peut-il s'elever : 10 ou 20 % par Watt ?

M. LANG pense que nos connaissances sur ce sujet sont trop vogues. Un tres grand nombre de plantes croissent tres bier, sans incandescence. Main pour le Pois p. ex., lo floraison est legerement affectee ; 8 Argonne Laboratory on a egalement constate que certoins Coleus ant besoin d'incandescence. Aussi, it semble qu'une addition de 10 6 20 %d'incandescence en Watt 8 la fluorescence est a retenir bien que "I would think that most plant

can do without it and that fluorescent tubes provide them sufficient energy in the long range to give quite good plants. But one point which we still think, an important one, is to provide perharps not optimal but at least reasonably good conditions for the maximum of plants ; this is quite important in phytotron and therefore we hove decided to keep

them on because they do".

M. BJORKMAN est du meme avis, qu'il trouve tres raisonnable, car "the higher is the fluorescent intensities the more important you will find that intensity is known to be". A ce sujet, it rappelle qu'ou Smithonian Institut, qui utilise des "output fluorescent tubes" places cafe 6 elate, les Chrysanthemes "don't grow normal any more, they were very suppressed in length growth and branch all over" mais si on ajoute en Watt 25 % d'incandescence they were normal again". Mais, conclut-il, "I don't think that in low intensity fluorescent light you would need incandescent light in addition".

4- Lampes a vapeur de mercure :

M. LEOPOLD indique qu'a Harvard, on utilise des lampes a vapeur de mercure a parois fluorescentes et reflecteur incorpore ; l'emission d'U.V. est fortement reduite par passage sur la couche fluorescente et conversion en orange. Dans son laboratoire it a installe un melange de ballon fluorescent a vapeur de mercure avec des lompes 6 incandescence.

M. VAN de VEEN se sert regulierement de lampes 6 vapeur de mercure lorsqu'il a besoin de fortes intensites. L'ennui, c'est la quantite d'U.V. dons ('emission (2557 A) mais les resultats obtenus sont mss satisfoisants. Ces lompes peuvent tres bien servir de lumiere d'appoint en hiver darts les serves.

M. MOHR trouve que dune lampe a vapeur de mercure 6 l'autre, it y a de grandes variations en ce qui concerne les radiations U.V.

M.DOORENBOS, tout en reconnaissant Pinter& des lampes 6 vapeur de mercure, prefere utiliser des tubes fluorescents car leurs dimensions donnent une meilleure repartition spotiale qu'une source pontuelle.

M. GAASTRA remarque que la proportion de radiations U.V. et violet dons ('emission est plus grande dans les lompes a vapeur de mercure haute pression que dons les tubes fluorescents. La transformation de l'energie electrique en lumiere est plus efficiente dans les tubes fluorescents aussi "if you want maximum energy put fluorescent tubes in all the wall surfaces".

M. DIMOCK rappelle ('action des U.V. de longueur d'onde variable et leur nocivite pour les plantes et M. VAN de VEEN signale que "If you put the plant coming from outside, at first, the plant is very damaged : leaves yellowing and fall of, but the new leaves formed are very resistant and so you have built up a new type of plant, who looks rather normal.I think it's the same difference when you grow plant in a mountain or at sea level. They look different but both are normal". II semble donc qu'on puisse utiliser des lampes a vapeur de mercure sans danger.

5- Lampes a Xenon :

M. MOHR utilise des lampes 6 Xenon uniquement come source ponctuelle dans le but d'obtenir des lumieres monochromatiques. Leur avantage est d'avoir une longue duree de vie : environ 2.000 hew-es sans changement appreciable ni dans le spectre ni du point de vue intensite. Les lampes de 6 kilowatts pourraient etre utilisees pour les chambres 6 culture mais elles sont a refroidissement 6 eau, donc d'installation delicate. D'autres modeles soot en tours de mise au point. Bien que ie prix en salt *eleve, it* n'est pas de I'avis de M. de LINT estimant que "they are cheaper than tungsten filament lamps in the long run as point sources. You need a lot of money for the first investissement but for a long run it pays back". De. plus, les prix de ces lampes diminuent.

M. KRAMER signale que le Dr STONE 6 Forestry School Berkeley (Calif. USA) utilise des lompes Xenon et en est tres content.

M. GAASTRA rappelle que M. MITCHELL utilise egalement des lampes a Xenon mais que dons ce cos le probleme majeur est You need only a few lamps for the big rooms and the spatial distribution of the lights is a real problem".

M.BOTTLAE NDER se sert egalement depuis 5 ans de lampes a Xenon avec reglage automatique de l'intensite mais estime qu'elles sont tres cheres et qu'il faut les nettoyer iournellement. Dans son loboratoire une installation automotique fait descendre les lampes le matin awes allumage et le soir les fait remonter avant extinction.

M.M. LINCK, LEOPOLD et BOTTLAENDER parlent d'utilisation de lompes a Xenon avec barriere d'eau pour enlever l'exces de chaleur. A ce sujet, M. BOTTLAENDER precise qu'il dispose dune chambre pour une plante avec refroidissement par film plastique, neige carbonique et alcool, donnant une tres basse temperature en surface : The radiation cooling goes to the plan:which is on a high light radiation and the CO_2 which evaporates at low temperature, falls down and goes between the surface and this skin of plastic and therefore there is no humidity and the CO_2 rises to the lamp and cools it and only light radiation comes to the plant with great intensity like in sunshine and the leaf temperature is not higher than in nature".

III- f) REFLECTEURS ET PEINTURE DES MURS

M. LEOPOLD propose de discuter "what is the ideal type of material to use for a reflector, either on the wall or behind the lamp ?".

M. MORRIS rernarque que, tres Frequemment, on observe un grand gradient lumineux dans les salles. Pour In diminuer,et en meme temps ameliorer la reflexion et reduire la deformation du spectre, par reflexion, it est utile de peindre les murs avec de la peinture blanche. A defaut, un film d'aluminium pur ou bien de ('aluminium recouvert d'une mince couche de plastique, par exemple, toile au mur peut facilement donner le meme resultat. Dans ce cas, le gradient d'intensite, ou le niveau d'intensite lumineuse, sera donne par soulevement ou obaissement des plantes par rapport aux lampes. Dans un espoce restreint principolement, donc un cabinet p. ex., it fout rechercher que the reflections of the light sources in the walls tend to give the effect of an infinite overcast sky. The light source is reflected to infinity in all directions and it gives an infinite horizontal light source in effect which give perfect uniformity of illumination in the space. This uniformity is not only uniformity aver the floor area and with bight it is also uniformity with direction and this is only get practically by pure cluminium in vacuum deposited form on the wall or in thin film Form".

M. BOTTLAENDER, qui est entierement d'accord avec M. MORRIS, indique que le meilleur reflecteur est ('aluminium a condition qu'il soil bien poll, outrement sa capacite de reflexion est variable avec le spectre.

M. LEOPOLD signale "this is easily available commercially, a Mylar sheet with aluminium filament sheet incorporated into it". Cependant, si le pouvoir de reflexion de ces films est tres bon, it est "much more efficient in reflecting the red and the infra-red wavelengths than it would the shorter wave...1engts".

Sur la duree de maintien de ces films d'aluminium, M.M. LANG et MORRIS precisent que tout depend de ('usage. II se remplace aisernent par collage et a Pasadena ce film 5'est maintenu pendant 4 à 5 ans sans deterioration.

M. BOTTLAENDER, comparant ('aluminium et la peinture blanche des murs du point de vue reFlexion **dir : "In** the spectrum the aluminium plates are not very good reflected in the visible lights, perhaps about 55 %; but in the invisible, aluminium is a very good reflective material". Dona ('aluminium absorbe une certaine partie de l'energie lumineuse &rise par les lampes et so temperature de surface augmente.

Une discussion technique entre M.M. MORRIS, BOTTLAENDER et CHOUARD fait apparaitre qu'il y a, bien entendu, plusieurs categories de films d'aluminium et que l'oxydation est assez rapide. Aussi M. MORRIS insiste-t-il en precisant que "with vacuum deposited aluminium you do not get the oxide, you do Rot get deterioration and the reflective coefficients is on the order of 90 *% or* more". C'est, en effet, seulement ('aluminium qui reste le bon reflecteur abseil" pendant un temps tres long.

M. MORRIS complete les informations sur ('utilisation de ('aluminium principalement en tont que materiau reflechissont sur les murs. II y a, dans ce cas, "an image of the light source over all directions and the effect is a continuous overcast sky, all the I ight is reflected downwards". Mais si on a de la peinture blanche sur les murs "which looks very bright to the eye but is not bright to the plants, because half of the light goes upward and the plants never see the light. So, the effect of this autoreflector is to have a large gradient of light in the cabinet, you get top of the cabinet a high light intensity with white paint and a very rapid fall-off with height. But with aluminium you get a low light intensity at the top where you are not interested in intensity, but a much smaller fall-off, and this is approaching the ideal which would be a horizanrol line if it were possible to get perfect mirrors. With the aluminium foil we use, this gradieni from100 % to 80 % and we think is about the best you can achieve with spectacle mirrors. Glass mirrors ore slightly better than the aluminium film, but much more expensive and not practical".

M. DOORENBOS prefere avoir, au contraire, dons les tulles un gradient lumineux lui permettant de disposer de 2500 fc en hauteur et environ 1200 fc au sal grace a des "adjustable trolleys" sur lesquels se trouvent les plantes. TI ne desire pas une reflexion optimale des mars peints en blanc mais "to have the light intensity as high as possible and we have a compromise".

M. VAN de VEEN attire ('attention de ceux qui etudient ractivite spectrale que "many of white points are refieating a tittle bit of far red if are radiated with blue and we have some difficulty to get really non fluorescent white paint'.

Bien entendu, comme le font remarquer M.M. NITSCH, LEOPOLD et MORRIS, it n'est pas possible "to get a perfect specular reflector and if you use aluminium foil it is slightly diffusing but it does not giving you the bad light distribution of white paint".

III- VERRE ET PLASTIOUES TRANSPARENTS - FACILITE DE NETTOYAGE

M. LEOPOLD, parlant de l'installation des lompes qui, genera lament, "are placed in a separate ducts" avec, du cote des plantes, un verre ou autre material) transparent, se demande quel materiau faut-il utiliser dans ce cas ? De rnerne, Mie REPP pense a la permeabilite spectrale des divers plastiques utilisables en comparaison avec le verre ordinaire ou aux diverses qualites de glaces pour les sen-es.

M. KLUETER signale que le fiberglass t " cuts out just a little bit more that the Mylar type barrier".

M. DIMOCK recant`oat que le fiberglass is translucent but not clear but it is much more pleasant to work under". Mats actuellement "we are specifying for all our chambers now clear U.V. transmitter plexiglass and we are using a tickness of quarter inch and we find that we have very little difference in light transmission when we go from a 16th up to a quarter inch tickness of the piexiglass". Sur une question de M. LEOPOLD, M. DIMOCK precise que pour le nettoyage c'est '`the same as with glass but it is a little bit more electrostatic due to the passage of air over the plexiglass. But the air is filtered before going over the lamp and over the barrier which can be easily removed from inside the chamber, pulled down and cleaned and put back up in a few minutes. We clean them oFf about once a month". Dans plusieurs cabinets, ii dispose d'un plafond lumineux qui se releve, permettant un nettoyage

Pour M. NITSCH, on pourrait peut-titre supprimer tout nettoyage du verre ou plostique en le substituont par un "air curtain" comme vou loft le faire le Dr SENN : "a sheet of rapidly moving air to separate the lamps from the rest of the cabinet". Mats, comme le font rernarquer M.M. LEOPOLD, CHOUARD, D1MOCK et KLUETER, ce dispositif pent etre utilise a ('entree des supermarkets ou pour separer les denrees surgelees, mais le principe ea toutefois different car "the cold air has a tendency to fall 50 it stays in and you have got the hot air staying up" (KLUETER). II serait egalement dans ce cos difficile, voice impassible, **de contrOler** l'humidite de l'air dans les sal les.

0

❑ 0

IV- HUMIDITE DE L'AIR ET DU SUBSTRAT

Bien que M. NITSCH estime qu'il y ait "very few reaction or very few proofs to the influence of various air humidity in cultivating the plants". M. SLAVIK ne pense pas que l'on puisse negliger ce facteur dans tout les cat. La-dessus, Mle REPP remarque que la secheresse du sol et la secheresse de fair sont deux problemes clif-ferents comme d'aillevrs ra montre le Dr TRANQUILINI a la suite de ses travaux au Phytotron de Patscherkoffel sur Pinus Cembra : The CO_2 assimilation with a few exceptions decreases still more with the dryer the air. This decrease of the assimilation is also seen in cases of plants which are supplied very good with water from the soil. In case of spruce it causes nearly absolute stop of the CO_2 uptake which means the stop of assimilation, for you can even see that in not so extreme conditions you also have this very prominent influence of the humidity of the air and that you must never neglect the humidity of the air in the Phytotron".

M.M. KRAMER, SLAVIK, BOGUSLAWSKY et Mie REPP potent alors la question : Comment mesurer l'humidite dans les salles climatisees : en valeur d'humidite relative ou bien en valeur d'humidite obsolue ou bien en-core en valeur de pression de vapeur, valeurs plus ou mains variables selon la temperature II semble bien que ('ex-pression la plus exacte soit la pression de vapeur, mais seulement comme le fait rernarquer M. SLAVIK : it is the best case only when we are expressing the humidity of air in vapor pressure as it is the best things we must take into consideration the temperature of the plant and not the temperature of the ambient air".

Pour M. ORSHAN, l'humidite est un facteur tres important dans le cas as l'on a en vue une cons-truction nouvelle car la maitrise de l'humidite est excessivement onereuse, et, surtout, de realisation tres delicate. II est regrettable que les ingenieurs qui travai dent au conditionnement de l'air soient peu familiers avec les exi-gences necessaires pour les chambres de cultures ; conditions fort differentes des pratiques ordinaires des industries frigorifiques ou conditionnement d'air de locaux d'habitation.

M. DIMOCK surencherit en estimant que "one of the reasons why we have not done more attention to the development of humidity control procedures is that it is expensive. It is very difficult to achieve simultaneous control of temperature, humidity, light, air exchange and other sort of thing and for that reason, perhaps, we have tended to shrug it off or put our heads in the sand. But I think it is For more important than the basic physiology of the plant than has been realized".

Etant donne le cot eleve de cette realisation, M. CHOUARD pense qu'il est inutile d'avoir dans tout les phytotrons un reglage possible de l'humidite, it suffit que dans quelques uns, comme p. ex. 5 Gif, ceci soit possible avec beaucoup de precision, mais alors dons ce cos, vu l'interet de ce probleme, se pose la question : "what kind of accuracy is necessary for the different problems dealing with relations of water with other important phenomena, for instance with photosynthesis ?". Ceci est une question qui est porticulieren-tent importante d'ailleurs, non seulement pour les phytotrons, mais egolement pour les chambres et cabinets de petites dimensions. Dans un phy-totron, it semble que l'on ne puisse descendre en-dessous dune precision de 2 a 3 %sans accroitre fortement le tout de rinstallotion.

M. KOLLER estime que pour la photosynthese une precision crenviron 10 % est suffisante, car elle n'apporte pas de grand ecart, mais cela depend bien entendu de la transpiration qui fournit environ 1 % de la teneur en eau de fair.

M. MOHR n'est pas d'accord avec la question posee sous cet angle car, pour lui, tout depend du probleme etudie, les solutions pouvant varier a l'infini et sont des cos d'especes.

M. EVANS pense et suggere que dans une grande installation, telle que Canberra, it faut "spend more money on humidity control only on a small proportion of the total facilities, which is about 1/8 to 1/10 of the total space"... and in that 10 %of space we control very accurately approximotivery 2-2,5 % of the plants over a very wide range". Ce contrOle fres rigoureux de l'hurnidite est surtout onereux aux basses humidites et a des temperatures elevees. Cette facon de proceder permet d'augmenter fortement les depenses pour la machinerie d'un espace restreint sans pour celo trop effecter l'ensemble du prix de l'installation.

M. GAASTRA remarque que "air humidity as such is no factor in any process, this is 'lust affecting the energy equilibrium of the water status of the leaves as determined by the uptake process and transport of water" et it estime que l'on peut toujours, sauf quelques cos particuliers, tourner la difficulte en changeant les conditions d'experience sans pour celo nuire ni au resultat obtenu ni aux conditions recherchees.

M. BOGUSLAWSKY met ('accent sur la precision dans la mesure de : "with the hygrometer in the air you cannot have more than + 5 % humidity" avec d'autres methodes peut-etre peut-on descendre a une meilleure precision 2,5 % cite par M.M. EVANS et SALISBURY ou meme devantage.

M. FRANZEL signale une methode a "refractive gloss containing a measuring element a osmium self psychrometer" mais qie personne ne connait.

Mi.°REPP indique que, selon son experience, une precision de 5 %de l'humidite relative serait suffisante dans les climats moderes aussi bien que dans les climats extremes. Un systeme de contrale est signale dans la description du "Phytocyclon" par M. WOLFF grace a on detecteur du point de rosee. De plus, it lui parait inutile, dans un phytotron, d'avoir routes les salles avec contrele de l'humidite et it suffit d'avoir, comme a Passziena, une settle ou deux salles avec cette possibilite.

Pour M. KLUETER, le controle de I 'humidite avec precision est possible mais limite par deux facteurs : le prix de ('installation et la dimension des salles. En utilisant du chlorure de lithium,dont la resistance change avec l'humidite, on obtient un contrOle valable et precis.

Mais M. MOHR rappelie que le chlorure de lithium, pour etre precis, ne dolt etre utilise que dans des gimmes restreintes et variables avec la concentration.

M.M. EVANS, DIMOCK et ORSHAN, discutant sur les detecteurs d'hurnidite au polystyrene, indiquent que selon certains experimentateurs, ('utilisation serait plus delicate que celle du chlorure de lithium. II n'en serait pas ainsi d'apres M. DIMOCK car dans In zone de "55 to 80°F and humidity levels from 35 to about 85%, we have been able to achieve control of whithin plus or minus 2 %" et cel a indifferemment avec l'un ou l'outre detecteur.

Mie REPP et M. WOLFF signalent une difficulte de regulation de l'humidite selon les temperatures. Difficult& tres apparentes lorsque lion examine le diagramme de Pair humide.

M. BRETSCHNEDER aurait constate une variation de sensibilite du chlorure de lithium selon la vitesse de ('air comparee aux renseigrvements donnes par un psyclIrometre, cette difference pouvont atteindre 10 % HR pour une vitesse de ('air de 0,1 3 0,2 m/sec. Cette erreur est superieure a celle observable sur un hygrometre ordinaire.

M. CHOUARD demande a M. KRAMER de donner son opinion 23 la suite de sec observations 2) Duke University, sur l'interet, ('importance et la realisation dans ern Phytotron nouveau du contraie de l'humidit˜e.

M. KRAMER estime que "we will attempt to make our relative humidity within the range that is feasible at the temperature at which we are working ; we will not expect to make independent infra factor artificially with many other factors". II pense egalement que les faibles humidites sent assez exceptionnellement utilisees et, en definitive, it faut chercher un compromis "between the greatest possible range and the practicality of cost". Une installation modeste realisant une humidite relative variable entre 55 et 85 % coute environ 500 dollars. Pour les serres, it faudrait simplement empecher In -chute de l'humidite au-dela dune certoine voleur.

M. BANERJEE pense que, pour les plantes tropicales, la question d'humidite est plus irnportante que Ion ne pense et, dans In cos de construction d'un phytotron pour ces plantes, the question of incorporating the extreme ranges of humidity is not just one or two sorts of compromises" et, darts ce cas, it est necessaire "to incorporating all *the* extreme ranges of humidity". Ceci, selon M. KRAMER, rejoindrait bien I'idee que "you design your equipment for your needs".

Bien entendu, comme le foil tres justement remarquer Mle REPP, les limites des precisions surtout et les besoins de contrale exact de l'humidite dependent des buts poursuivis mais, a la mise en place d'un phytotron, it fout essayer de penser a tous les problemes ofin de rendre ('installation aussi polyvalente que possible,et permettont lo resolutions des recherches dans tous les domcrines.

N.B. Etant donne les difficultes *de* reglage de l'humidite de Pair, on a adopte a Gif-sur-Yvette la temperature humide de Pair qui est determinee par une sonde psychrometrique se trouvant dans le tunnel venti le de la salle. Cette falcon d'operer donne une precision de fonctionnement de + 0,3 a f 0,4°C. en temperature humide, peu importe a quel emplacement du diagromme de lair humide on se trouve. Ceci equivaut a un maximum de 5 % en humidite relative, pour Pair b son entrée dans la salle.

⁂

V- TENEUR EN GAZ CARBONIQUE DE L'AfR

M.M. DOORENBOS et CHOUARD donnent rapidement un opercu de nos connaissances en *ce* qui concerne ('action du CO_2 qui, sur certaines plantes, est nette, p. ex. : Laitues, Tomotes, Oeillets, mime en hiver lorsque la lumiere pourrait etre un facteur limitant de la photosynthese, mais qui, pour un grand nombre d'especes, ne semble pas agir. Au printemps ou en ete, les observations sur le role du CO_2 sont beaucoup plus difficiles a faire car on ne peut fermer les serres par suite de la temperature. C'est une question que Ion peut etudier dans un Phytotron, mais ('installation du contrale et de la regulation du CO_2 est ossez onereuse *et,* semble-t-il, lo question devrait etre entierement reprise et etudiee a nouveau.

Aussi, M. CHOUARD pose-t-il la question *du CO_2 : "* Is it an important question for Phytotron 2" Est-il necessaire de le contraler partout ou seulement dans quelques pieces ou petits cabinets ? On esrime qu'un recycloge de ('air avec admission de 5 a 10 %d'air exterieur suffit pour les plantes ; est-ce certain ? A Gif, on a constate que la teneur en CO_2 de ('air varie sensiblement tout **au** long de la journee comme de Pannee. Comore, d'autre part, let wiles ont un 6ciairage intense, "nous avant pease serait interessant de maintenir la teneur en CO_2 de ['air a ('entree, a un niveou eleve constant, par exemple 4 milliemes de CO_2 par enrichissement artificiel". Cette idee est-elle a retenir 2

M.M. MOHR, VAN de VELN SALISBURY, LINCK et BJORKMAN, font part de leurs observations sur faction du CO_2 dont on peut donner le résumé avec M. VAN de VEEN: " The different quantities (of CO_2) reacted in such a different way, that were quite a few (species) that reacted favorably, and there were others that did not react and there were even ones that reacted by growing worse *and* turning yellow. So as you see the action of CO_2 depends on the species".

Mle REPP dernande : "it is necessary in an Phytotron to control the CO_2 ? Are we in danger to get a deficiency in CO_2 so that becomes a minimum of smaller or bigger chambers 2" et dons ce cos se posent les questions : "What is necessary to control ? Do I want to know how much CO_2 is in already or do I want to keep it on a certain level ?"

de contreler la teneur en sucre qui est stocke dans la plante aux diverses époques de l'annee. Le rapport annvel de l'Institut presente cette etude en entier.

M. KRANKEL estime qu'un grand nombre d'autres questions protiques pourraient 'etre resolues et principalement les questions de nutrition minerale des plantes et application des engrais, car it y a, dans ca cos, un Fres grand nombre d'interactions diverses que le phytotron permettrait de denouer.

M. GALUNremctrque que tout les phytotron soot relativernent jeunes et seul celui de Pasadena au Caltech a plus de dix arc. peut-titre toys les chercheurs qui y ont passe Wont pas resolu beaucoup de questions mail i) foot pour celo °Rendre encore et peut-titre merne augmenter leer nombre pour voir d'autres utilisation.

0
o o

VII- COOPERATION INTERNATIONALE - AIDE DE L'UNESCO

M. CHOUARD, abordant le probleme de cooperation, constate qu'entre un pays developpe et un pays en vole de developpement, it n'y a qu'une difference de temps, de periode au d'epoque. Un phytotron fres onereux nest peut-titre pas necessaire directement 5 ces pays, mass plutat des unites ou parties de phytotrons ou serres ameliorees d'abord. Les quelques grands phytotrons existent claivent servir d resoudre les problemes fondamentaux importants et generaux. Du point de vue cooperation, ii y a trois problemes :

I- Relation perrronente, echanges d'informations, rencontres, colloques, etc...
2- Examen des propositions de ('UNESCO.
3- Que faut-il faire ensemble ? Peut-Ctre le probleme du Programme Biologique International (1.B.P.) serait-il soulever ?

M.M. GAASTRA, FRANKEL et JARVIS evoquent la possibilite de reunir en une publication qu'on pourreit appeler "Phytotranic newsletter" (Frankel), financee par ('UNESCO, toys les divers modeles de travaux traites par ou dans les phytotrons et les descriptions &installations phytatroniques qui, actuellement, soot rejxtrties dans des "botanical or techni cal papers) (Gaastra) et que "some of the technical problems may have been solved, but are they the right ones for physiological study" (Jarvis). Un regroupement de tout en une seine publication presentereit beaucoup &intern.

M. LANG ne pense pas que les cours de phytotronistes soient d'actualite, &ant donne que lo phytotranique ne peut encore etre consideree comrne une science, aussi it faudrait un temps tres variable pour mettre au point l'instruction a donner : court ou breve visite ? La situation *est* ici completernent differente de Celle existent pour "Soil Science" (evoquee par M. FRANZLE et M. WALTER) car it y a dela *une* Science de la Terre. De plus, it n'y a pas asses de phytotrons. A Pasadena, par exernple, M. LANG ne petit recevoir dix personnes err stage car it serait oblige, dans ce cat, de reduire le nombre de chercheurs.

M. fRANKEL est egalement du meme avis, de mime que M. WASSINK, qui estime que les Coors d'entratnement sort un peu prermstures, surtout a grande echelle car, en dehors de quelques speciolistes, on ne trouvera pas suffisamment de professeurs.

Mais, pour M. KOLLER, it foudroit faire des cours pour avoir " a better understanding of the environment especially in growth cabinets and also for to interpret the results of their experiments". Pour cele, it foudrait trailer les problemes"on the physics of the plant environment and micro-meteorology, perhaps the root environment, etc...". Ceci se restrinant plus par "few demonstrations of what can be done and how to interpret, what safeguards • to take when reading this information".

M. CHOUARD resume les idees ; it semble qu'il y a *deux* oblectifs differents ; des cours d'entrarnemerit UNESCO, de on ***a*** deux mois, lets que les envisage M. KOLLER, specialement axes sur la physiologic vegetale et la physiologic ***de*** l'environnement, qui pourreient titre domes dans les phytotrons existents. L'autre objectif est celui que petit reellement apporter ('UNESCO aux pays en vole de deveroppement et, dans ce cas, it faut envisager, avant k: construction &us phytotron, un stage d'un an ou deux pour les futurs phytotronistes, °fin de participer au travail reel dans an phytotron.

M. BOATMANN estime que [es cours d'ent rainement ne doivent pas prendre le temps compler des chercheurs mais etre "part-time operation".

Pour M. NITSCH, une bonne pantie des cours sont deja dispenses avec la climotologie **01.1 pl Oa}** la bloc I imatologie.

Et pour M. GALUN, ces cours doivent s'adresser el des personnes ayant deja Fini leurs et***udes*** et 6 un petit rrombre de personnes "who are responsible For the technique of running the phytotron".

M.M. WASSINK, JARVIS, LEWITT et SALISBURY toulevent egalement de nornbreux problemes evoques au cours du Symposium, et qui montrent que les phytotronistes eux-memes ne connaissent pas encore

et les court de perfectionnement leur paraissent donc peu real istes et prematures.

M. NANDA pense que, puisqu'on a decide de posseder un phytotron, "it is important to have proper personnal to main that phytotron", par consequent, les court doivent etre mis stir pied. Pour cela, it faut deux tortes de personnel : "one For the technicians who will be concerned with the handling of the phytotron and they should have a separate type of training from those who will be the research workers". Pour les seconds, des visites de divers phytotrons sont importances pour avoir une idee "about their working and spend some more time in the type of phytotron that they are going to built in their own countries".

M. BANERJEE est completement d'accord qu'il y a lieu de separer l'aspect technique et l'aspect recherche. C'est pour ce second groupe de chercheurs, déjà docteurs, que ies court d'entrainement seraient utiles. Ces court devraient etre suivis par des visites de phytotrons-types ou d'Universites ou d'Institut participant **OW(** travaux des Phytotrons.

Pour M. BOATMAN, ii y aurait cependant an certain danger a separer le personnel en deux groupes "I think any system which encourages people to use phytotrons which they can't themselves control is perhaps rather a danger, Perhaps it would be wrong to emphasize the gap between the scientific and technical assistance. li propose plutot ('inverse : envoyer du personnel specialise pour "assist in the setting up of new environmental facilities in a developping countries during one or two years". A son avis, un echange frequent du personnel entre let divers phytotrons serail souhaitable.

M. BOGUSLAWSKY pense, neanmoins, que ('organisation par l'UNESCO de cours de perfectiorrement est parfaitement realisable pour des post-gradues qui sont axes sur l'Ecologie et la Physiologic. Seale se pose le question de duree de ces court.

M. BOUILLENNE signa le qu'en Belgique des Congolais viennent ***re9ulierement*** se perfectionner dans les divers laboratoires et acquierent un certificat. II en est de meme, d'ailleurs, dans d'outres pays qui accueillent des Africains.

M. KENDE suggere que, puisque ('UNESCO s'interesse a la question, it faudrait creer "some sort of advisory committee composed of people From several regions and countries who could be responsible For the news paper and also for suggest some Further training if needed".

M. BANERJEE estime que, pour eviter des surcharges de personnes et de matieres, les cours d'entrarnement devraient etre donnes "for peoplewho will be engaged in future in the work on environmental physiology and who have a sufficient background of grasping the things of environmental physiology that are attached in a phytotron".

Pour M. FRANZEL egalement, les cours de phytotronistes doivent etre plutOl des cours de "plant physiology or ecology or environmentalism, with a special attend on the application of phytotrons as means of research" et qurils doivent etre differents de ceux d'ingenieurs ou techniciens speciolement pour les pays en vole de developpement.

M. WALTER precise qu'a ('UNESCO it y a un "Advisory committee" qui contrOle tow les programmes de sciences naturelles, main it y a aussi une division qui coordonne tous les travaux scientifiques et ce n'est qu'avec l'avis, et apres accord de ('United Committee for Natural Ressources Research, que sont executes les programmes specifiques. C'est d lui qu'il y a lieu d'envoyer des propositions concretes.

M. CHOUARD pense en conclusion qu'il n'y a pas lieu actuellement de piendre de decision ou proposition. D'obord, it foul un compte rendu des seances et attendre ensuite les reactions des divers participants avant de proposer quelque chose a ('UNESCO.

M. FRANKEL propose de penser ('installation d'un grand centre phytotronique quelque part aupres d'un grand centre agricole, p. ex. : "Rice Research Institute in Philipin" et les fonds seraient demand& au Programme Biologique International.

M. CHOUARD estime que le programme biologique international dolt etre soigneusement etudie d'abord et ensuite presente par M. FRANKEL et lui-meme.

⁂

VIII- AUTRES SUJETS DE DISCUSSIONS POSSIBLES

Molgre le grand nombre *d'idees* emises el de sujets abordes ou cours des deux journees de travail, it reste encore un aussi grand nombre de themes de discussions proposes , main qui n'ont ere qu'evoques et insuffisamment discutes par manque de temps.

En voici la liste. Elle peut presenter un certain interet pour d'autres reunions. Les norns qui suivent les propositions de discussions suggerees sont ceux de leurs auteurs ; d'autres qui n'ont pas de noms d'auteurs viennent du personnel du Phytotron de Gif-sur-Yvette.

A- PROBLEMES TECHNIQUES

a) Diverses conceptions des Ph otrons (entretien, gestion, emploi de ces diverses sortes de Phytotron ; adaptation aux problemes a resoudre).

- Phytotron technique compared advantage of various techniques (H.R. HIGHKIN).
- Optimum size of cabinets (J .P. KRAMER).
- Phytotron technique : chambers, versus rooms (H.J, KETELLAMP
- La creation de nouveaux Phytotrons *et* dimensions a donner a ces installations encore inexistantes (P.E. PILET).

b) Progrespossibles ou recherches en vue des divetses operations techniques dans les Pl..otrons.

1 - Cl imatisotion, temperature, humidity, etc...

- Problems of CO_2 control, humidity of air, light (.1. CATSKY).
- Problem relating to the use of high intensity light, humidity control, continuous variation of temperature and light intensity (F.B. SALISBURY}.
- Comparaison du mouvement lateral, ascentionnel 04:descendant de I'air.
- Exposure chambers and humidity control for photosynthetic measurements and water research (B. SLANAK) .
- Aspects of controlling the environment in Phytotronics Techniques (H.R. HIGHK1N).
- Soil temperature, microclimatology of the Phytotron (H.]. KETELLAPPER).
- The measurement of temperature in growth room in relation to light (G. HUSSEY).
- Definition de la temperature d'une salle, compte rendu du rayonnement.
- interet de l'etude de l'hygrometrie de l'air.

2- Lumiere.

Problemes d'illumination des cabinets controles des Phytotrons (E.L. NUERNBERGK).

- Proportion of naturally lighted vs. artificially lighted cabinets (J.P. KRAMER).
- E,ight sources and sunlight (H.J. KETELLAPPER).
- Possible comparison for quality effects of sunlight with fluorescent light quality (F.P. ZSCHELLE).
- Attainment of light intensities under controlled conditions (A.H. BUNTING).
- Present possibilities concerning generation of light of high intensities (H. MOHRI.
- New artificial light sources (W.W. SCHWABE).
- New development in lighting and refrigeration (A.J. LINCK).
- Light conditioning use of Phytotrons for photosynthesis and chlorophyll studies (Z. SESTAK).
- Relations between the qualities of the phytosynlbetic apparatus and environment (P. HOLMGREN).
- Growth of plants in artificially illuminated rooms and cabinets under high intensity illumination (J.J. PALMER).
- Control of spectral composition of light (C.D. NELSON).
- % incandescence-fluorescence a utiliser.

- Intensity et quolite de la Ivrniere d'appoint.
- Light quality- control and measurement (A.W. CALSTON). - Precision necessaire dans les mesures d'intensite lumineuse. - Methode de contrale de l'intensite iumineuse et son maintien a un niveau acceptable en fonction de la lxiisse

de flux des lampes avec leur age.

Probleme du passage progressif des conditions de lour aux conditions de nuit, *et* vice-versa (A. ANSIAUX).

3- Techniques culturales, programmes.

- Milieu de culture : substrat, solution nutritive.
- Degree of quarantine which is necessary in Phytotron . P. KRAMER).

4- Contrale

- Supplying several climatic factors at the ..same time in small rooms (C.D. NELSON).

5- Construction de petits cabinets.

- Evaluation of the commercial boxes now available (J.E. GUNCKEL).
- Reasonable requirements on range of environmental factors, to be specified for environmental room (J.E.GUNCKEL).

6- Limites possibles

- Limitations of Phytotronics research (S.H. CAMERON).

B- PROBLEMES SCIENTIFIQUES .-

Quelles recherches scientifiques (fondomentales et appliquees) exigent-eiles le plus expressement l'emploi d'un Phytotron ?

- The level of environmental control necessary to allow extrapolation of results from the Phytotron to natural conditions (R.O. THOMAS).
- Les diverses questions relatives aux recherches que les Phytotrons permettent de cleanser (P.E. PILET).
- Use of Phytotron (J.A.D. ZEEVAART).
- Interactions between environmental factors and growth (J.A. LOCKHART).
- How the Internal conditions of the plants relate to the external factors (G.G. SPOMER).
- Questions of what degree of control is needed to obtain valid results and how to successfully transfer the Findings in the laboratory to the field (H. HELLMERS).
- Comparisons of results from Phytotrons and the field (J.P. HUDSON).
- The use of Phytotron facilities to study problems arising from study of crops in the field (M.P. CARTWRIGHT).
- The use controlled environments for study of agronomic problems (J.H. HUDSON).
- Usefulness of Phytotrons in analysing the relationship between plants and their natural environment (D.G. MORGAN).
- The use of controlled environments for studying effects of climate and weather on crop yield (D.J. WATSON).
- Fact that most work in plant physiology has dealt with plant growth and other responses at light intensities quite low in comparison to out-door sunlight. Many genetic differences and other responses might well be different if high intensities were employed.
- Light intensity and quality effects on plants (F.P. ZSCHELLE).
- Effects of different root and shoot temperatures on plant growth (LA. MOORE).
- Effect of age and stage of development on the rote of Photosynthesis (M.P. CARTWRIGHT).
- Tree Physiology and Phytotronics of woody species (Dendrotron) (S.D. RICHARDSON).
- How Phytotron must help for application to problems of plant ecology and causal plant geography (M. RYCHNOVSKA).
- Effect of environment on plant virus mutation and selection (J.C. BALD).
- Un semi-phytotron permettant de resoudre certains proble-nes de Phytophysique alpine (P.E. PfLET).
- Finding from experiments in Phytotron (F.L. MILTHORPE).

C- PROBLEMES DE COOPERATION .-

a) Cooperation scientifique et Technique entre Phztotronistes.-

- The Phytotron as an inter-institutional and an inter disciplinary facility (D. KOLLER)
- International cooperation in Phytotronics (H. MOHR).
- Cooperation in Phytotronics (R.D. ASANA).
- Cooperation : regional large Phytotron combined with local small.facilities (H.J. KETELLAPPER).
- Exchange of experiences with different types of Phytotrons (K. EGLE).
- Exchange of scientists between Phytotrons (A. NYGREN).
- Establishment of on international center of information concerning the engennering of controlled climatic conditions (E. GALUN).
- Opportunite de creation dune societe de Phytotronistes (P.E. PILET)

- Livre Irk bref enumercnt les diverses facilites qu 'tare choque phytotron, darks le but de permettre aux chercheurs de realiser des experiences plus certoinement valables selon les possibilites (P.E. FILET).

- Brochure enumerant les diverses facilites que l'on petit trouver dons les divers Phytatrons et par extension dons les diverses Facultes et Stations de Recherche.

b) Cooperation en vue de l'oide aux poems en voie de developpement, yecialement aux zones arides.-

Questions posees par I PUN ESCO

- Importance of Phytotronics for arid zone research M. EVENARI).
- Cooperation of different countries in Phytotronics for arid zone (N. EVENARI).
- What requirements should be fulfilled to make a Phytotron useful (craning of personnel, associated research, etc..) (0.H. FRANKEL).
- Courses for technicians and research workers and cooperation of Phytotronists developing countries (K.K. NANDA). - Le probleme des chercheurs et stages que ceux-ci pourraient faire dons les Phytotrons (P.E. PILET).

- Needs of UNESCO (F. LONA).

c) Cooperation eventualiement en rapport avec le Programme Biologi ternationcl .B.P.)

- Eventuallement, repartitian du programme des recherches sur les focteurs de l'environnement agissant quantitativement sur la productivite.

- Nature of assistance in Agronomy and research could be give by Phytotron (0.H. FRANKEL).

- Intensified connection with the International Biological Programme (W. HAUPT).

0

0 ❑

RESUME ET CONCLUSIONSDE LA REUNION PHYTOTRONIQUE I -

(Londres, Juiliet 1964).

Le recut du temps permet de reprendre les deux fours de Conferences et Discussions particulierement interessontes de la Table Ronde Phytotronique tertue ii Londres les 30 et 31 juillet 1964 et, cares, un resume adapte aux circonstances, de firer des conclusions elargies et actuelles.

I- RESUME

Quatre principaux chapitres ont ete abordes :

1 / <u>DESCRIPTION DES PHYTOTRONS, SERRES AMELIOREES, CABINETS SPECIAUX et DISPOSITIES OU "GADGETS"</u> utilises pour pallier les inconvenients de its voriabilite climatique de plein air.

C'est ainsi qu'ontete presentes (parfois avec ('orientation des principales recherches entreprises)

: - Le Loborotoire d'Horticulture de READING (Dr HUGHES).

- L'Institut d'Horticulture de WAGENINGEN (Prof. DOORENBOS).
- L'Institut d'Agriculture de RAUISCH-HOLZHAUSEN (Dr BRETSCHNER10).
- L'Hel iotron de GORSEM (Dr SIRONVAL).
- Phytocyclon et Phytobox (Ets RIJTHNER).
- L'Institut de Biologie de BAYER de LEVERKUNSEN (Dr BOTTLAENDER).
- Diverses facilites du Phytotron de GIF-sur-YVETTE (Dr NITSCH).

O
O 0

Cette liste n'est, Bien entendu, qu'une petite partie des nombreuses realisations existantes et it sereit interessant que, dans le cadre d'eventuel les "PHYTOTRONIC NEWSLETTERS", sait entrepris le recensement des d iverses installations existantes dans le monde, avec, dans cheque cas, une description aussi detaillee et concise que possible.

Ce travail pourrait etre entrepris rapidement, sous forme dactylographique d'abond pour etre reuni ensuite en un volume general.

O
O 0

2°/ FACTEURS DE L'ENVIRONNEMENT, MOYENS DE CONTROLE ET DE MESURE DE DIVERS DEGRES DE PRECISION .-

C'est dans ce chapitre que Pon pent inclvre environ la moitie des discussions et deux conferences sur les mesures de lurniere.

a) Temperature :Plusieurs problemes abordes n'ont pu cependant trouver, de conclusion generale, car tout depend du but poursuivi. Dans cet ordre d'idee, citons Moyens de mesure de la temperature des Feuil les et comporaison avec cel le de fair ambient ; influence de l'alternance des temperatures et, surtout, possibilites, difficultes et degre d'interet du reglage de la temperature d'ambiance en fonction de la temperature de la plante.

b) Humidite : Pour ('ambiance, la maitrise de l'humidite est fres onereuse et, semble-t-il, pas tovjours indispensable. Pour l'humidite du substrat, Pautomatisme est possible, mais son utilisation doit dependre do but poursuivi.

c) Goz carbonique He de lo malirise precise de ***ce*** facteur ne paroit pas evidente (comple tenu du prix et des difficvltes d'instellation), soul' lorsqu'il s'agit de problemes de fertilisation carbonee. II senble qu'avec une bonne aeration et on bon renouvellement d'air, le probleme deviant secondaire, mais, la encore, les conclusions peuvent etre differences scion le but poursuivi.

d) Lumiere : Sur ce sujet deux conferences ont etc presentees. La premiere par le Dr NISHIZAKI sur la methode utithee d l'Institut d'Agriculture de TOHOKU, pour mesurer sur place, a ('aide de plaque photographique, l'eclaire-Cent et lo report ition spectra le.

La seconde par le Dr GAASTRA sur la methode de conversion des mesures permettant des comparaisons en vaIeur energetique des diverses lampes. Avec les lampes fluorescenies les plus puissentes, on atteint environ 45 %de la lumiere estivale de WAGENINGEN, mots II Foul alouter environ 60 % d'incandescence pour compenser le deficit des rayons rouges et infra-rouges proches.

Durant les discussions, it est apparu netlement que le type de lampe et reclairement optimum dependent du but poursuivi et de lo duree des experiences.

De nombreux points poraissent peu connus ou encore insuffisamment discules, notamment le degre d'interet 6 porter 6 la variation progressive de l'eclairernent au debut et a la fin de Pherneroperiode, le vieill issement des lampes et Ia baisse de flux avec la duree le rapport Fluorescence S incandescence y a lieu d'utiliser dons l'eclairement des plantes, la qualite de la peinture des murs ou de surfaces reflechissantes sur les murs et ('utilisation des verres ou plastiques pour separer les lampes de ('ambiance.

Les iompu a arc a xenon donnent, indiscutablement, les niveaux d'eclairements les plus 'Sieves avec un spectre assez sembiable ou spectre solaire, mais leur prix et certaines incornmodites en limitent l'emploi ii des cos spec ia ux .

Pour toute installation, une methode sage consiste, d'une part a realiser des essais prealables permeltant d'obtenir des plantes oussi semblables que possible a celles desirees, et d'avtre part a decrire avec soin les conditions d'eclairage et mesures d'eclairement reelisees ofin de permettre Ia reproduction des experiences.

a o

le recul du temps nous permet de signaler que toutes les personnes interessees par la Phytotronique onr rep dons le courant de 1965 une note sur Les diverses lempes existent sur le marcher avec leurs caracteristiques d'intensite lumineuse et leurs spectres d'emission. II semble que depuis cette epoque peu de re:nivel:lutes client ete mites sur le march&

it semi' interessant, egalement, dans le cadre eventuel de "Phylatranic Newsletters" de donner la liste du materiel servant 6 mesurer les divers parametres de temperature, humidite *et* lumiere principalement.

o ❑

3°/ UTILITE DES PHYTOTRONS - COMMENT DOIVENT-ILS ETRE ? COMPARAISON DES DIVERS TYPES - BESOINS EN PHYTOTRONS

Ce chapitre essentiel, principolement pour les nouvelles installations, a ete longuement delxittu. **II** semble que, id encore, tourdepend du but poursuivi.

Trois conferences generoles ant compare les moyens existents et defini comment devrait etre un Phytotron nouveau.

Pour le Dr KOLLER, un Phytotron devrait pouvoir donner an gradient permanent d'un certain nombre limits de facteurs permanents avec possibilite d'introciuction de gradients temporaires supplementaires. Les facteurs permanents sons principelement : temperature et lumiere. La valeur d'un Phytotron depend de sa Flexibilite.

Le Dr NITSCH ne pense pas qu'un grand Phytotron, avec des seller de grandes dimensions, soit necessaire dans tote les pays. II comporte, en eFfet, one perte de place due d une machinerie compiexe et exige un personnel important et quaiifie, et c'est pourquoi it prefere, du mains pour son usage personnel, la formule des serres conditionnees sans exces de precision (= superserres) pour les experiences preliminaires et des petits cabinets pour des essais precis, principalement ceux de courte duree.

Le Dr EVANS a precise encore, semble-t-il, la pensee generale en clossant les parametres par ordre decroissant d'importance : temperature, photoperiode; niveau d'eciairement, humidite, vitesse du vent, composition de l'air, *etc...* mais, selon cet auteur, on devrait touiours avoir la possibilite de faire varier separement les temperatures des parties aeriennes et souterraines des *Nes. La repartition de la surface d'un Phytotron devrait etre analogue a cells de Canberra : 1/5 seulement de In surface totals avec une regulation tres precise du maximum de facteurs, done d'installation, et d'entretien Tres onereux.

2/5 en eclairage naturel avec une precision de temperature de + 1,5 °C, entre 15 et 36°C et une duree du jour de 8 ou 16 heures, et 2/5 en cabinets a eclairage artifitiel avec la niece fourchette de temperature, ma's avec une precision de temperature superieure.

Au tours des discussions les miimes conclusions sont apparues : melange de grandes sales et de 'Deli is cabinets dormant le maximum de flexibi lite

line recommendation evidente a etre ((lite pour le choix des emplacements de futurs ensembles : preference pour la proximte d'un Centre de Recherche 3iologique.

Six Conferences ant fait apporaitre l'interel des P.hytotrons :

- Le Dr HUGHES a Reading, etudie les problemes horticoles.
- Le Dr BRETSCHNEIDER a Rauish-Holzhausen ayant etabli an programme climatique moyen, variable par periocle de 5 jours, determine par des essais sur avoines les conditions moyennesqui to rapprochent le plus de la region, en prenant pour base le rendement poids de grain et de pail le ainsi que le rapport grain-paiiie. II lui parait que cette methode est voluble pour toutes les plantes,ou mains ceiles des regions temperees.

- Le Dr BOTTLAENDER 6 Leverkuessen, utilisant des elements en platine, constote qu'ils soft influences de is ***mime*** fawn que la plante par la temperature ***de*** Pair, la vitesse du vent et les radiations lumineuses. I I a &oblides courbes de croissance des plontes par calcul de polynomes de regression. Ces courbes de croissance lui servent aux essois d'efficacite de pesticides divers.

- Le Professeur BOGUSLAWSKI 6 Rauish-Holzhausen, a etudie,sur l'avoine,l'action du gaz corboniqueet les changernents physiologiques qui apparaissent en combinant ce facteur avec la temperature, l'eclairement et la nutrition azotee. I I estime que c'est grace au Phytotron gull a pu isaler of seporer faction de cos divers focteurs.

- Le Dr COOPER ***a*** Aberystwyth (Ecosse) a compare des vorietes de Lolium, Festuca et Dactylis d'origines mediterroneennes et ecossaises. Dans ce cos, un Phytotron precis nest pas necessaire, et des salles avec un haut niveau d'eclairement ont etc suffisants. Dans le meme laboratoire, le Dr BIRCH a poursuivi ce travail en comparant des plantes cultivees dons des parcelles d'essais a l'exterieur et dans les salles, ce qui lui a permis de determiner quels sont, parmi les facteurs les plus variables, ceux qui interviennent le plus sur ies phenomenes etudies.

- Le Professeur NANDA, de l'Universite de Penjab, ne pout, par contre, terminer le travail commence en 1941 sur 260 varietes de froment par manque de Phytotron. Malgre les nombreuses correlations elaborees entre divers focteurs exterieurs, la croissance, le metabolisme of le developpement des froments, it ne peut verifier la classification physiologique etablie en se basant nut le quantum photothermique, la croissance des parents et le developpement reproductiF.

Au cours des discussions, it est apparu nettement que la plupart des problemes déjà poses ou connus peuvent et doivent etre tabard& sans utilisation de Phytotron. Par contre, ii y a encore trop peu de recherches faites dans les Phytotrons pour pouvoir juger de leur rentabilite.

Pour les utilisations pratiques, it a etc rappele que les resultats obtenus ne peuvent etre transposes directement, surtout du point de vue des touts de production, car les conditions de travail dans un Phytotron sant toujours differents de ***cel*** ies des travaux accomplis dans la nature.

o
o 0

Lerecul du temps nous perrnet de constater que Ion a encore peu de nouvelles des grandee installations qui ant ***ate*** realisees depuis 1964. Le Biotron du Professeur SENN aux USA et un Phytotron en URSS 6 Irkoutsk semblent etre, selon nos connaissances, **Its** seules realisations de grande envergure; quelques autres paraissent etre en preparation. Par contre, presque chaque Faculte, presque chaque Departement de Physiologic vegetale et chaque Service de Recherches en Agriculture, dispose actuellernent,ou aspire vivement a disposer, de serres de culture avec plusieurs cabinets en 6c 10 irage artificiel pour les etudes precises, c'est-6-dire de disposit ifs qui, sans etre de veritables Phytotrons, relevent de ce que nous appelons ici la "Phytotronique". Les idees emises ou cours de cos "journees consacrees, en 1964, 6 la Phytotronique" paraissent en vole de trouver une application un peu partout dans le monde.

o
0 0

4°/ COOPERATION INTERNATIONALE .-

Sur ce chapitre, une seule intervention, celle du Dr FRANZLE, a fait ressortir les facilites qui pourraient eventuellement etre demondees a UNESCO :

- d'une parr la creation de "tours pour Phytotroniciens"
- &mitre part publication de 'Phytotronic Newsletters·'

et On pourrait y ajouter onnuellernent la publication de resumes (=abstracts), rediges par les interesses, sur les articles parus sur les questions interessant la Phytotronique.

Au cours de la discussion, 71 est apparu que seule la publication de "Phytotronic Newsletters" est d'actualite, les autres possibliites ne sont pas encore mixes.

Par contre, la mite as point dans les Phytotrons de quelques problemes interessont le programme Biologique international, pourrait titre envisage.

0
00

Les quatre annees passees depuis la reunion ont permit de canstater que plusieurs organismes internaronaux, par example !International Society for Horticultural Science (ISHS) s'inleressent egalement au prolleme de l'environnement en reunissant des Congres, Colloques et Conferences generates ou specialises.

On peut titer les reunions internationales suivantes qui touchent taus as certains des problemes evoques a noire Table Ronde. Cette lists, non exhaustive bien entendu, merite d'etre reproduite ici afin de souligner ('importance que prennent les problemes de l'environnernent dons les recherches *at la* vie rnoderne :

- Symposium on plant environment in glasshouses Silsoe 13-17 septembre 1965 ; Commission for Hoiticul rural Engineering from ISHS ;
- Symposium of Measurment of Environmental Factors in Terrestrial Ecology, march 1967 - Reading ;
- Symposium on the Techniques of experimentation in greenhouses. Littlehampton 3-7 april 1967 ; Commission For Protected cultivation from ISHS.

4eme Congres International de Chouffage et de Clirnatisation ; Paris, Mai 1967.

- Symposium on Electricity and artificial light in Horticulture; Littlehampton 17-21 march 1969 ; Commission for Horticultural Engineering from ISHS.

Soil, en rnoyenne, un peu plus d'une reunion annuelie internationale dont nous avons eu connaissance. Mois la ne s'orrete pas ('effort entrepris car certains centres de recherches et Universites ant forrement elatgi l'accueii des stagiaires strangers et principalement ceux des pays en voie de developpernent. Sans peut-titre dormer de "cows'", ni delivrer de "diplOrnes" de Phytotronistes, ces stages permettent d'avoir des notions plus precises des besoins et des difficukes de [a recherche utilisant les moyens phytoironiques.

On pourrait, semble-t-Il, commencer d penser plus serieusernent a une organisation plus coherence et a une diffusion plus complete des inoyens et possibilites de perfectionnement.

N. de BILDERLING

II- CONCLUSIONS

On a dispute beaucoup sur le point de savoir si les Phytotrons ont servi ou serviront, oui ou non, a faire des decouvertes importantes en science fondamentale ou pour des applications importantes en vue dv "bien etre humain" ? II sembie ressortir de lo discussion que les biologistes du monde vegetal, en 1964 n'etaient pas encore assez generalement informes des moyens d'action de la Phytotronique pour en definir unaniment l'emploi dans les domoines de la science en gestation. Par exemple, tres peu de personnes savaient olors qu'il n'y a d'interet a employer les moyens onereux d'un phytotron proprement dit que sur un materiel bien connu auparavant, bien "clefini" sous le rapport de ses reactions aux divers facteurs du milieu, de sorte que l'emploi des phytotrons etait parfois gaspille avec peu de profit. Comprendre la necessite moderne pour la Biologie vegetale de faire usage de divers moyens de mattrise des facteurs de l'environnement en passant par diverses &apes d'entrainement et de precision, est un &at d'esprit qui se repand, mais ce n'est qu'un commencement.

On sent venir d'autre part un engoi:Iment croissant des Biologistes vegetaux pour la Biochimie, la Biophysique, et meme la Biologie theorique ; on pourrait croire que, d'une certaine maniere, la Biologie tend a devenir une branche de la Chimie, de la Physique ou meme des Mathernatiques. Cependant, nest-ce pas, pour une part du moins, avec ('aide de la Phytotronique que se degagera dans I'avenir l'originalite de la Biologie vegetale ?

En effet, la Phytotronique est le moyen indispensable pour s'affranchir des "bruits de fond" du milieu naturel afin d'entendre, de decouvrir et de situer, les complexites spatiales, temporelles et autres qui, s'aioutant aux donnees physico-chimiques de base, permettront d'apprehender les premiers elements de ('emergence de la vie.

P. CHOUARD

ERRATA

PHYTOTRONIQUE

COMPTE•RENDU DE LA TABLE RONDE TENUE AVEC L'AIDE DE L'UNESCO

LONDRES 30 - 31 JUILLET 1964

POSTFACE 7969

<u>Page 60- lignes 33 et 34</u> lire :

....very large differences in glasshouse conditions, but little difference at the lower light intensities of the artificial-light growth rooms.

<u>Page 67- lignes 7 a 22</u> lire :

LANG- The relation between reproductive development and vegetative growth is generally recognized, but the big question is : is this a genuine , causal relationship or a <u>correlation</u> of which the physiological bases are not understood ? However, I'm afraid that if we go into a discussion of the scientific aspects of any of the papers presented here we will infringe on the prerogatives of the Botanical Congress which we all are going to attend ; thus, I suggest we do not discuss that question. A point that occurs to me in this connection again, however , is : when do we need a phytotron, and when can we do with a couple of well-controlled , commercial or self-made growth rooms? From what you said I do not feel that you are absolutely dependent on a medium-size or large-size phytotron, but that much of what you intend to do could be accomplished with a much less elaborate and less expensive facility. I am not saying this to question that there is a need for phytotrons in a country like India, but to bring up once more the point already touched upon several times in our discussions, namely, that we should first have a pretty good idea of the type of problems we want to work on, and on this basis decide what type facility is required.

<u>Page 67- lignes 32 a 38</u> lire

LANG- The one common denominator of the three papers we have been hearing this morning is the question, to what extent and how can phytotrons help us with our more practical problems.Dr. Nanda's study, apart from its fundamental or theoretical aspects , is also an eminently practical one, for I suppose you would like to determine exactly which varieties of a crop plant are best suited for the different parts of your country, and this is a problem which is present in many other countries, too. This question has also been proposed for discussion by a number of contributors who have submitted specific questions for discussion. We might thus well take up such a general discussion at this point, (N, B. The discussion which followed is included in "Compte-rendu des discussions, VI. Besoins et utilisations des phytotrons", pp.97-100 of this volume).

Page 87- lignes 17 20 lire :

M. LANG ne pense pas comme M. MOHR. Il estime que les installations "depend firstly on what we want to do.If we want to study specifically questions of light adaptation, or effects of spectral composition, or photoperiodic responses, etc. our needs are quite different than if all we want to do is to grow plants under standardized conditions. Secondly, the present main light sources in phytotrons are fluorescent lamps.But fluorescent lamps made by different companies in different countries are not identical, and are not always obtainable in any country.In Pasadena, I can easily buy General Electric or Westinghouse lamps but cannot obtain, at least not as easily, certain foreign makes. The same is probably true, although in the opposite direction, in other countries. The complete unification of light sources which Dr. MOHR advocates is thus difficult to achieve for such technical reasons, at least without investing additional effort and perhaps money for which in most cases there is no genuine need. Thirdly, the manufacturers are constantly experimenting with lamps.Even if we could agree to use in all phytotrons a single make of fluorescent lamps from a single maker we would have no guarantee that this make would not have changed, more or less, in a few years. Moreover, I am not at all convinced that fluorescent lamps are the last word as light sources for phytotrons or artificial-light growth cabinets.If we standardize all phytotrons and cabinets with one existing kind of lamps we may be shutting off ourselves from new and perhaps revolutionary developments in the science and technology of light sources. Thus, unification of light sources seems to me not really necessary, difficult to accomplish for practical reasons, and as a matter of fact perhaps outright undesirable".

In conclusion, the question "fluorescent/incandescent" is a wide open one and may change profoundly as we are slowly inching up, in phytotrons and growth rooms, to light energies similar to solar radiation ".

Page 89-lignes 33 a 40 lire :

M. LANG pense que nos connaissances sur ce sujet sont encore beaucoup trop vagues pour nous permettre de proposer des "rapports" plus ou moins desirables ou bien pour formuler des regles specifiques.Actuellement,lorsque dans les Phytotrons on utilise comme source principale d'eclairement des lampes fluorescentes a flux eleve un tres grand nombre de plantes croissent assez bien sans adjonction d'incandescence et si l'on ajoute de l'incandescence on n'observe pas de differences morphologiques ou physiologiques notables. Nous avons cependant constate a'. Pasadena que pour le Pois, la floraison est legerement acceleree si l'on ajoute environ 10% d'incandescence; 'a'. Argonne National Labotatory on a observe que certains Coleus ont apparemment un besoin absolu &incandescence. Aussi, pour des raisons purement pratiques et actuellement it semble qu'une addition d'environ 10 a. 20% d'incandescence en Watt a. la fluorescence peut etre retenu bien que " I think that most plants can do without it and that fluorescent tubes, at the energies presently used, provide sufficient energy, in the long wave range to produce quite good plants. A practical point, but an important one, is that we may want to provide a maximum of plants perhaps not with optimal, but with reasonably good light conditions.If we look to the future, however, we should be ready to change our thinking.In the few cases of which I know, where the light energy from fluorescent lamps has been raised to nearly the level of sunlight the growth of plants has not only not been improved, but seems to have become considerably poorer. This was not relieved by addition of light from incandescent lamps at the currently used ratios (i.e., ca. 10 - 20%) .On the other hand, as far as I know no similar, unfavorable effects have been noted when the energy levels from incandescent lamp were raised. B.S.MOSHKOV, in the Agrophysics Laooratory in Leningrad, has in fact returned to the exclusive use of fluorescent lamps for plant growth and seems to be getting excellent results with a high efficiency of light utilization. (The work seems to be published mostly in places not readily accessible; therefore I have to say this with some reservations .)

Page 97- lignes 28 a 31 lire :

M. LANG pense que ces deux points ne'cessitent une complete discussion. "But it is very important that we assess the needs as we see them, that is , at first without considering the practical, i.e. financial questions which will have to be faced when it comes to implementation. Therefore, let us first take a very detached view and look at phytotrons as though money was•no limiting factor. Later we can turn around and see what might be done as long as money is still rather scarce. On this basis, we may arrive at a reasonable assessment of the need for phytotrons and how far it can be met ".

Page 98- lignes 17.a 28 lire :

M. LANG estime que M.KRAMER pose ainsi " **a** very precise and challenging statement" avec lequel it est entierement d'accord.Il ajoute toutefois qu'a Pasadena" the main deficiency I have felt was the lack of sufficient facilities for certain, extreme conditions".Car "just subjecting a plant to drought or to low temperatures does not require a phytotron; it can be done in much simpler installations However, the stress resistance of the plant depends not only on its condition at a given moment, but changes with development and may be influenced by its past environmental 'experience:A plant is much less frost resistant when it is in an active state of growth than when it is in a reduced state of growth or complete dormancy.And a plant which was raised under one set of temperature and photoperiod conditions may respond to low or high temperatures differently from one raised under another set.In order to study responses to freezing, drought, etc . we thus need not only facilities for these particular treatments but also facilities to control the growth of plants in a reproducible manner and to know their exact 'environmental history'-in other words, here we may really need a phytotron and nothing less.I was quite impressed when I recently had an opportunity of visiting Soviet Russia to see how much care and thought, and space and facilities they have put into work of this kind.It seems to me that because they have this combination of 'ordinary'controlled facilities and at the same time, e.g., huge rooms in which they can expose a whole little cherry tree to temperatures of, I believe almost liquid nitrogen, they can make quite interesting contributions to frost injury and resistance, and similar problems".