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Phytotron
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PHYTOTRONIC NEWSLETTER N°17

CONTENTS

News and Miscellaneous information

I - EDITORIAL

As announced in the two previous issues, in this issue we finish publishing the series of papers and communications presented at the 1975 Congress of Botany in Leningrad reviewed by their authors.

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Certain financial difficulties delayed the appearance of issue 16 which could only be sent out at the end of the year and not in August 1977, as originally expected. For similar reasons this issue n° 17 appears after a long delay : January 1978, not October 1977. We ask our readers to excuse us for these unintended delays.

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We thank the many readers who write encouraging us and ask them to excuse us for not replying owing the secretarial difficulties. We also thank everyone who has very kindly sent us financial help. As always, we ask you to send us your financial help, mentioning : "Participation aux frais de parution de Phytotronic Newsletter", labelling it : "A l'ordre de l'Agent Comptable secondaire du CNRS, 4eme circonscription, 91190 Gif-sur-Yvette, France". Postal cheques and money orders have to be labelled : "A Pordre de l'Agent Comptable secondaire du CNRS, 4eme circonscription. CCP Paris 913848 U Paris".

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This issue includes the three usual chapters :

a - Meetings. - We mention only three meetings and are sorry not to be able to include others because of a lath of information. We still hope that our requests and calls will be better received in future.

b - Research strategy, papers and scientific notes. - These are the communications from the Leningrad Botanical Congress. One interest of these articles is that two third of them are published by Soviet colleagues whose work is not widely known.

c - Information and news. - For this chapter please do not omit to let us know of any events which you know,

Finally we ask our readers to send us any documents, information, technical notes or scientific articles relating to fundamental or applied research in vegetable physiology or horticulture which might, interest all "phytotronists".

Thanking you in advance,

R. Jacques and N. de Bilderling

II - INTERNATIONAL SYMPOSIUM ON AGRICULTURE IN A CONTROLLED ENVIRONMENT

Tucson, Arizona, U. S. A. - 7-8 April 1977

J. Cl. Garnaud, one of the participants in this symposium has very kindly sent us the following report which was also published in Plasticulture 1977, n° 34. We are pleased to **reproduce** it here since we think it is likely to interest our readers.

The reputation of the Research Laboratory on the Environment (ERL) of the University of Arizona is already well-known. Its mission is to study and develop advanced techniques for the production of water, of energy and of food under difficult conditions, particularly in arid zones and to put those systems in operation at specific locations in order to increase the food resources, to economise in energy usage and to improve the standard of living.

Each year, the Laboratory organises a colloquium in collaboration with the College of Agriculture. In 1976 the topic was "The use of solar energy in greenhouses and in integrated systems greenhouses/dwellings" (report $ 5. 00). In 1977, the chosen subject "Agriculture in a Controlled Environment" and the international status of the meeting considerably enlarged the potential attendance and attracted all the more specialists (about 300) as the date preceded the Congress at San Diego by only a few days.

Among other things, our **hosts in** Arizona stressed the considerable advantage resulting from the strong sunlight : water can be transported but not the sunlight. With such circumstances, should the greenhouse growers in the north give up? For the moment, if one is to believe G. F. Sheard (Littlehampton, U. K.), reporter for Western Europe, J. M. Jacobs, (Naaldwijk, Netherlands) for Eastern Europe and Suichi Utsumi (Association of Agricultural Co-operatives in Japan) nothing is likely to portend a set-back for crops grown under protection in regions where they are handicapped by limited sunshine but have the advantage of the closeness of large consumer markets, of their advanced technology and competent workers.

Even in Canada, the construction of 2 hectares of greenhouses in Ontario adjacent to an existing complex of 272 ha (166 ha glass and 106 ha plastics) bears witness of a certain optimism in spite of problems arising from fusarium and tomatoes imported from the south.

However, in the States, some economists such as M. E. Cravens have shown the weakness of northerly installations, particularly those in Ohio where about 200 ha (480-500 acres) of the 300 ha (750 acres) of the vegetable growing in greenhouses in the country are concentrated. If a comparison is made of the consumption of fossil fuel required for the production and dispatch of the tomatoes to the market at Cleveland, very different values are obtained depending on the point of dispatch :

	BTU /lb tomatoes
Heated greenhouse in Ohio (but no transport costs)	67,000
Greenhouse in California, slightly heated	27,035
Open air in Florida	1,400
Open air in Mexico (transport)	3,805

Likewise, the costs of production of $ 56,494 per acre in California increase to $ 69,200 in northern locations.

It must be recognized that the advancement of crops grown under cover or partial cover is much more rapid in the Mediterranean regions than in the north of Europe (J. C. Garnaud, CIPA) and this boon applies also to the Middle East (Henry Spice. UK and Alfred Cox, Iran).

However, in the south as in the north, cultivation in conditions which are becoming more and more artificial and at higher and higher densities, implies the need for more precise control of all the environmental factors - both the biological factors (genetic qualities of the plants, defense against hostile attacks) as well as physical factors,

The forty odd papers presented at Tucson, as well as the discussions, made up a wealth of up-to--date information on the various aspects of cultivation in a controlled environment.

Information on the colloquium can be obtained from : Merle H. Jensen, Research Horticulturist, Environmental Research Laboratory, Tucson International Airport, Tucson, Arizona, 85706, U. S. A.

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VIIth INTERNATIONAL CONGRESS ON PLASTICS IN AGRICULTURE

San Diego, Calif. , U. S. A. - 11 -16 April 1977

M. Garnaud, General Secretary of International Committee on Plastics in agriculture (CIPA) has kindly sent us the present report which we feel should be of interest to our readers. The same text was published in Plasticulture, June 1977, n° 34.

1974: Buenos Aires, Argentina.
1977 : San Diego, California.

Two landmarks in the history of plasticulture. Two sites evocative of conquistadors, galleons loaded with gold and spices, of the legendary Americas... Two towns separated by thousands of miles, one facing the Atlantic, the other the Pacific, one in the southern hemisphere, the other in the northern hemisphere.

They are located in two countries which are radically different in their political, economic and agricultural structures.

The very large area of the United States accounts for the fact that research workers and technicians work in regions as far apart and different as New Jersey and Hawaii, Alaska and New Mexico and have the need for exchange of experiences.

At the opening of the Congress, the Vice-President Robert W. Grove recalled that since the development of interest in plasticulture by Prof. Emmert of the University of Kentucky, the National Association (American) for Plastics in Agriculture (NAPA) has organized twelve conferences, the thirteenth being part of and incorporated in this, the Seventh International Congress.

Norman Smith, the President of NAPA, presenting a comprehensive picture of what plastics have done for agriculture and horticulture, stressed the social consequences of plasticulture which thanks to improved yields assures the future of the world for the young.

After words of welcome from the Mayor of San Diego, Dr. Charles Hess, Dean of the College of Agriculture of the University of California, presented a detailed analysis of the close interdependence between Californian agriculture and the laboratories and stations of research (in this spring of 1977, the water reserves fell from 60 to 75 % due to the drought and posed a particularly alarming problem which the University specialists worked with industry to resolve). Certain writers, however, would like to reduce the medium of research, guilty in their eyes of reducing labor by increasing productivity. From their side, economists insist on the determinant role which agricultural production plays in the commercial balance of the country and its politics - in spite of these contradictory opinions, the University of California continues its work of research and teaching (4. 700 students) and maintains to intensify exchange of information ; in exchanging a dollar, one has each a dollar, but in exchanging an idea, one has each two ideas.

<u>Lectures and papers.</u>

Plenty of ideas have been exchanged at San Diego between some five hundred participants in spite of the lack of simultaneous translation facilities which was criticized by the foreign delegations.

A hundred or so papers were presented and discussed, a third of them came from overseas, Australia, Brazil, Canada, France, Great Britain, India, Iran, Israel, Italy, Japan, Jordan, Mexico, Holland and Switzerland. The requirement to use the English language to the exclusion of all others prevented attendance by a certain number of specialists from the Latin countries and also participation by the members states of COMECON.

About half the communications related to irrigation particularly to the techniques of trickle or drip irrigation with all the detailed aspects and the applications envisaged for the economic use of water which is a world wide problem.

Other presentations were concerned with mulching (it is surprising that it has not been more widely adopted), low tunnels, cover sheets, fumigation and naturally greenhouses (all the work had as common denominator - research for a better use of energy and particularly solar energy), packaging, etc.

It may be surprising that there were so few papers on applications as effective and promising as windbreaks, shading, silage, water reservoirs, soil drains and agricultural buildings (particularly stock raising). Several lecturers have drawn attention to materials such as polyesters which are being reassessed aid those under development such as radiation cross-linked polyethylene and PVC for the manufacture of tubes and fittings which are more heat resistant and have better mechanical strength, UV stabilized polyester films and polybutylene.

The proceedings of the seventh International Congress will contain a wealth of information.

£he exhibition.

The actual presence of equipment and materials constituted a very welcome additional element to the somewhat theoretical character of the conference sessions. The exhibition was, moreover, very much in keeping with the work of the Congress in that irrigation was the dominant subject and occupied about one third of the sixty-five stands. There was an abundant suppl4 of samples and technical literature and this may have perhaps posed some problems of excess baggage to participants faced by a long return air trip !

Programme of visits.

This proved to be very successful, due mainly to :

1. The wide range of the applications of plastics in agriculture and horticulture in California : Victor Voth described those used with strawberries but many others were seen at the same time in the greenhouses for cut flowers at Encinitas, for foliage plants at Vista, in the orchards for avocados at Puerta del Sol and Monserate Hill, for citrus fruit and actinidia at Calle de la Vista.

2. The scale of the fittings using plastics for cultural techniques, for example for the protected cultivation of tomatoes extending like a sea at Oceanview or the vast hills which are now planted with fruit trees because of the use of drip irrigation.

3. The continuing innovations in plasticulture in California by both users and constructors ; the equipment produced by Great Lake Chemicals which does three operations at the same time (fumigation, laying the polyethylene mulch film and also the drip irrigation tubing) is a good example amongst many others of the continual efforts for progress.

4. The trouble taken by the organizers ; in addition to notices and panels describing the equipment of the technical sequences of the application, numerous demonstrations have allowed delegates to compare the various methods of soil

fumigation both in the open and in greenhouses, the setting out of low tunnels and the attachment of films on greenhouse structures (notably double wall).

TA should be added that the agricultural advisers from the country of San Diego, who were selected because of their linguistic abilities to accompany the French and Spanish speaking groups, showed themselves to be guides of high competence.

The whole team of organizers is to be congratulated and thanked for their hard work and efficiency. We should draw special attention to the incomparable patience shown by the ladies of the reception committee, all unpaid, and the guiding influence of Bernarr Hall. Their merit is all the greater since the public authorities refused to help and the American industry for plastics materials seem to have conspicuously measured its support.

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IV - IVth INTERNATIONAL CONGRESS ON PHOTOSYNTHESIS

Reading, U. K. - 4-9 September 1977

Nearly 1.000 scientists participated at this important congress. **12** symposia were organized on different scientific subjects with about 500 lectures, communications or posters. It is absolutely impossible in practice to give a summary of everything ; for this reason we give only the titles of symposia with in each case the number of communications :

Symposium 1 : Light harvesting and reaction centers.
5 reports, 32 contributed papers and 47 posters.

2: Photosynthesis in cells and tissues.
5 reports, 16 contributed papers and 15 posters.

3: Organization of electron transport.
5 reports, 31 contributed papers and 36 posters.

4: Photosynthesis and productivity.
4 reports, 18 contributed papers and 16 posters.

5 : Carbon metabolism.
5 reports, 27 contributed papers and 19 posters.

6: Photo system II and 02 evolution.
5 reports, 16 contributed papers and 28 posters.

7 : Regulation of metabolism.
5 reports, 16 contributed papers and 20 posters.

Symposium 8 : Development of photosynthetic systems.
5 reports, 36 contributed papers and 45 posters.

9: Photophosphorylation and ion transport.
5 reports, 28 contributed papers and 25 posters.

10 : Solar energy conversion in biology.
4 reports, 6 contributed papers and 6 posters.

11: Photosynthesis and food.
4 reports.

Plastocyanin Symposium. Properties and function of plastocyanin. 9 reports.

Those interested in receiving additional information or a summary of the communications should kindly write to : UKISES, 21 Albemarle str. , London W1X 4BS, U. K.

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V - THE USE OF AIRTIGHT, DAYLIGHT, CONTROLLED-ENVIRONMENT CABINETS FOR FUNDAMENTAL AND APPLIED PHYSIOLOGICAL STUDIES OF CANOPY PHOTOSYNTHESIS

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The principal advantage of artificially-lit cabinets is that they provide the experimenter with complete control over the duration and flux density of the radiation to which his plants are exposed. However, some plants show abnormal growth under artificial light because its spectral quality differs from that of daylight. (Although xenon lamps emit radiation with a spectral power distribution similar to that of daylight, at least in the visible part of the spectrum, they are not widely used because of their cost and the problems of eliminating spatial and temporal variations in radiation flux density). To avoid this abnormal growth, which invalidates the *use* of artificially-lit cabinets to predict the behaviour of these plants in the field, a number of experimenters in the last 20 years have built daylight cabinets (Schwabe, 1957 ; Read et al. , 1963 ; Zscheile and Neubauer, 1967 ; Hoffman and Rawlins, 1970 ; Gensler, 1972).

The varying radiation flux density in a daylight cabinet makes it difficult to interpret growth analysis data or any crop responses which integrate changes in environmental factors over hours or days. However, it is now possible to measure net CO2 assimilation by plants over a few minutes and relate this to the radiation flux density over the same period. To facilitate these CO2 flux measurements, several daylight cabinets have recently been constructed as nearly airtight as possible.

At G. C. R. I. the airtight, daylight cabinets are regarded as intermediate between (a) artificially-lit cabinets, in which the fundamental properties of single leaves and plants are studied, and (b) large-scale field or glasshouse crop trials. To simulate field conditions as closely as possible the daylight cabinets are large enough to hold a representative section of crop canopy with the plants growing in soil or individual pots. Since it is not practicable to wheel these sections of crop from one cabinet to another, each cabinet can be programmed to give a wide range of environmental conditions.

The prototype daylight cabinet at G. C. R. 1. consists essentially of sides of 6 mm plate glass and a top of 10 mm armoured glass bedded on "non-hardening" mastic in a frame of 29 mm steel angle (Fig. 1). The transparent plant space is cubic with sides 2.15 m long. Within the space, 154 mm from the east side is suspended a 6 mm sheet of "Pe. Rspex" extending across the whole cabinet, with a 160 mm gap at the top, forming one side of the return air duct.

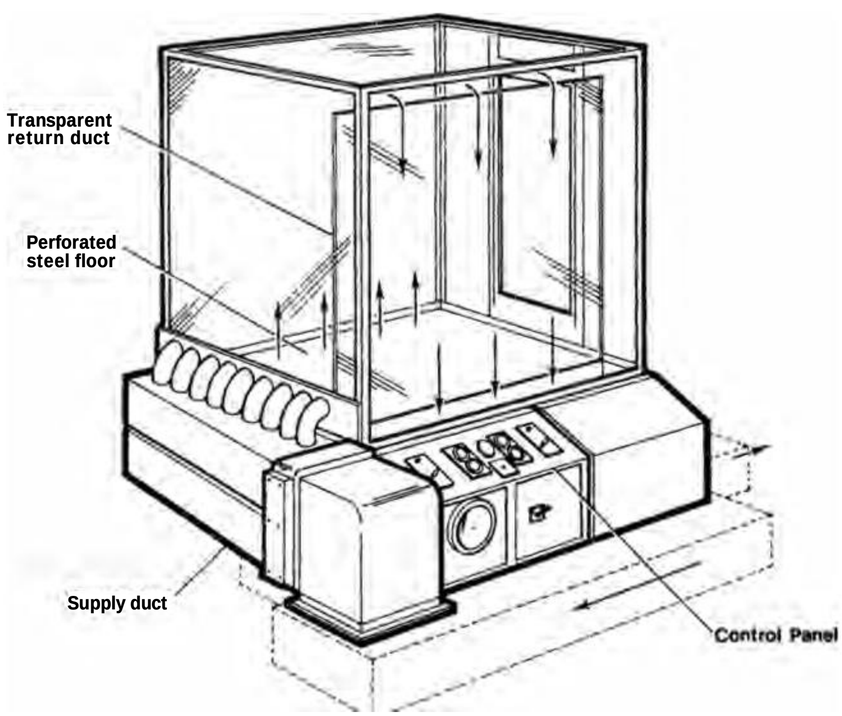

FIG.1. The G.C.R.I prototype, daylight cabinet viewed from the south-east.

The cabinet has a temperature range of 10 to 30°C and dewpoint control of relative humidity in the range 80 to 90 % r. h. at 10°C and 45 to 90 % r. h. at 30°C. The rate of vertical airflow past the plants is 0. 4 m sec $^{-1}$ which is equivalent in this cabinet to one circuit of air every 12 seconds. The lowest leakage rate achieved so far is 0. 02 air changes per hour. Further details of the daylight cabinet have been published by Acock (1972).

A null balance method is used to measure the net canopy photosynthesis of crop stands over intervals of 10 minutes. CO2 concentration is controlled to within 0.5 % of the desired value. The amounts of CO2 used in canopy photosynthesis are measured with a linear mass flowmeter accurate to ±10 mg CO2. The total errors incurred in the measurement of crop photosynthesis are estimated to be of the order of ± 30 mg CO_2, i. E. ± 0. 75 % to ± 2. 5 % over a range of solar radiation flux densities from 100 to 450 J $xn^{-2}s^{-1}$. For further details see Hand (1973).

During the time the prototype daylight cabinet has been operational, light response curves have been obtained for canopies of tomato, sweet pepper, aubergine, tulip, rose and chrysanthemum. To compare the photosynthetic productivity of C3 and C_4 crops under comparable experimental conditions, CO2 assimilation measurements have also been made on Amaranthus edulis. Models of canopy photosynthesis have been applied to the measurements so as to explore the relationship between environmental factors such as light and CO2, canopy structure and the optical and photosynthetic characteristics of individual leaves.

Light response curves for "Sonia" (syn. "Sweet Promise") roses at three CO2 concentrations have been obtained by the use of a mechanistic model of canopy photosynthesis (Hand and Cockshull, 1976), The results suggested that if cut flower production is positively correlated with photosynthetic rate it should be of benefit to enrich the glasshouse atmosphere with CO2 under winter light. In collaboration with a commercial rose producer the long-term benefits of CO2 supplementation on the quality and output of bloom production have now been established on a commercial scale, and in view of the increased cash returns to be gained from three- or four-fold CO_2 enrichment, growers have been encouraged to adopt the technique as standard practice (Hand and Cockshull, 1977). With controlled environment daylight cabinets it is now practicable to study the dependence of net photosynthetic rate of crop stands on environmental and crop parameters before formulating and testing new growing methods in longer-term glasshouse trials.

Acknowledgements.

We are grateful to Academic Press Inc. for permission to reproduce Figure 1 from "Crop Processes in Controlled Environments".

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VI - A GUARANTEE OF CONTROLLED ENVIRONMENT PARAMETERS IN PHYTOTRONS

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1 - Technical solutions of Phytotrons and requirements for thermic installations.

In biological research programmed artificial climates are being used more and more. With this aim in mind, Phytotrons are being built and are being planned in the URSS. The Phytotrons in use are : at the Institute of Plant Physiology of the Academy of Sciences in Moscow, at the Institute of Plant Physiology and Biochemistry of the Siberian section of the Academy of Sciences in Irkoutsk, at the A. K. Timiriazev Agricultural Academy, at the V. Lomonosov State University in Moscow. These various Phytotrons are devoted to fundamental research.

The following is under construction : the Phytotron of the Vaskhnil Inter Republican Institute of Selection and Genetics in Odessa. Several Phytotrons are planned at the Interrepublican Institute of Scientific Research on Oleaginous plants and at the Interrepublican Institute of Scientific Research on Rice in Krasnodar, at the Institute of Selection and Production of Wheat seeds in Mironovka, in the region of Kiev.

As for the structure and the organization, two types of Phytotrons are found :

. autonomous ones, not attached to the Scientific Research Institute complex, and
. those which are part of a Scientific Research Institute.

The first type comprises, generally, a relatively large number of auxiliary services and workshops; in the second type, these auxiliaries are reduced to a minimum, because they are part of the Institute. However, two types of Phytotrons are, actually, isolated industrialized buildings, made up of an area for the preparation and the supply of various energies and nutritive solutions and areas for basic research and for installations (greenhouses, growth chambers and growth cabinets).

Phytotrons for research for first approach can be classed according to the characteristics reproduced in Table 1.

The research Phytotrons include : greenhouses with filtrating curtains, complementary artificial lighting and darkening installations ; growth chambers and artificial light cabinets ; laboratories ; rooms for the administration and communal rooms, places for machines where air conditioning units are found, refrigeration and thermic installations, control and regulation rooms, supplementary services ...

Table 1. - Classification of research Phytotrons

classification characteristics :	general features of research work	research characteristics
destinations :	polyvalents	complex research on numerous plants and on diverse problems
	with one single aim	complex research on a single plant or the study of a single question but on diverse plant species
degree of exactness of permanent parameters :	very precise	complex and very precise experiments
	simplified	relatively simple experiments for which there is no need to have great precision for the microclimate

The planned size of the Phytotron building depends on the following factors : main orientation ; geographic position ; relief of the terrain ; natural lighting conditions and the influence of the surrounding forest crop or plantation on the lighting regimen ; characteristic, concentration and dispersion of dust, noxious gases and fumes from neighboring factories ; the influence of meteorological factors and the sun's radiation.

Of particular importance is the exact choice of the form of the greenhouse lay-out and construction and their disposition in an area with spaces for the preparation and the feeding of various energies. The greenhouses must not be shaded by nearby structures. The form of the greenhouses and the orientation in relation to the sun depends on the period of use, the character of the experiments being done and of the locality's latitude.

A permanent and efficient functioning of the systems of heating, ventilation, air conditioning, lighting, thermic installations, water and air supply sewerage system and the automatic regulation of all the systems determines the possibility for carrying out uninterrupted energetic biological research which frequently is of long term duration.

All the technical solutions used must have as well a maximum of safety. The sources of production and supplies of electrical energy, of steam, of heat, of cold and of gas, as well as ventilators, compressors, pumps, air conditioners must, in case of need, be able to be doubled or else to be isolated.

Lighting systems must allow for modification, according to the established program, of the length of the photoperiods, the light sources and their combinations. They must assure, in greenhouses, in growth chambers and cabinets indispensable lighting with a spectral composition of suitable light for photosynthesis.

These systems of heating, ventilation and air conditioning must automatically maintain in the growth chambers optimal parameters of the artificial climate during the various growth periods.

In the case of new phytotrons being planned, it is absolutely indispensible to coordinate various architectural solutions for construction and setting up, for engineering in order to come to the optimal favorable solution. Thus, for example, the choice of the height of greenhouses with transparent separations must be determined in terms of the desired level of lighting, the characteristics of complementary lighting lamps, their height and disposition, the height of the plants, temperature distribution, humidity, air velocity in the plant zone and finally, temperature tolerances of the leaves.

Air temperature is the main factor determining plant growth. At each stage of growth there is a corresponding optimal temperature for day and night. However, air temperature is closely linked to other climatic parameters and can vary in terms of lighting variations, soil humidity, relative air humidity and air velocity. In relationship with all of the above, the temperature limits proposed initially must be, in case of need, corrected with the help of biological researchers.

Relative air humidity has an influence on plants' transpiration and in large part determines the conditions of development of pathogenic microorganisms and the possibilities for plant infection. The speed of air movement influences also transpiration, soil evaporation and of carbon dioxide absorption by the plants.

The Phytotron of the Timiriazev Academy of Agriculture (TCXA) (2) is in a way a division of autonomous research, and for this reason, its laboratories represent about 30 % of the total surface (Table 2).

In existing Phytotrons having relatively simple ventilation and air conditioning systems, 22-40 % of the space occupied is for a machine room, experimentation areas (greenhouses, growth chambers and cabinets) occupy 11-23 ⁰7₀ of the total surface.

Table 2. - Surface distribution in existing phytotrons

areas	surfaces of these areas in the Phytotrons					
	TCXA (2)		Inst. Pl. Phys. (1)		Irkoutsk	
	sqm	%	sqm	%	sqm	T_o
air conditioned greenhouses	201	21, 76	100	1, 68	144	5, 48
ordinary greenhouses	-	-	-		160	6, 08
growth chambers	19, 5	2,11	559	9, 33	168	6, 39
growth cabinets	-	-	9, 5	0, 16		-
machine rooms	206, 1	22,31	2110	35,23	1089	41,40
laboratories	282, 7	30,61	730	12,19	400	15,21
offices, amphitheaters, exhibition rooms, library	-	-	1210	20,20	-	-
dependencies and communal areas	214, 4	23,21	1270	21,21	669	25,44
total surface	923, 7	100	5988, 5	100	2630	100

The Phytotrons under construction in Odessa, Mironovka and Krasnodar (Phytotrons of the Institute of Oleaginous cultures) come under the Institute of Scientific Research complex, which disposes of the so-called Phytotrons, the buildings with laboratories and the dependent and communal areas. In these Phytotrons, there are practically no laboratories or areas for measurement work. In such conditions areas destined for plant experiments are predominant, as well as machine rooms destined to receive machinery systems.

Table 3 gives spatial distributions in the machinery, areas of the Phytotrons.

Table 3. - Distribution of surfaces in phytotrons under construction (engineering)

Areas	Surfaces of these areas in phytotrons					
	Odessa		Mironovka		Krasnodar	
	m2	%	m2	%	m2	%
air conditioned greenhouses	1360	10, 54	1244	6, 9	2995	12,14
non air conditioned greenhouses	660	5,12	830	4, 6	-	-
growth chambers	608	4, 71	407	2, 25	560	2, 27
growth cabinets	176	1,36	243	1, 35	135	0, 55
vegetation greenhouse	-	-	227	1,26	-	-
seed storage chambers	42	0, 33	263	1, 46	54	0, 22
machinery room	7600	58, 91	9944	55,1	10015	40, 6
laboratories	81	0,63	137	0, 76	112	0, 45
control rooms and electric power station	75	0, 58	695	3, 85	859	3, 48
dependancies and communal areas	1200	9,3	1111	6,15	7916	32,1
soil preparation	-	-	234	1, 3	543	2, 2
halls, corridors, vestibules	1100	8,52	2712	15, 02	1478	5,99
total surface	12902	100	18047	100	24667	100

Table 3 shows that in phytotrons under construction a large surface area (between 40 and 59 %) is reserved for the installation of control equipment and indispensible conditions for the execution of experimental research. Laboratories, only, represent about 1 % of the surface and that used for experiments about 20 %.

It should be noted that a similar surface distribution is in part determined by the method of carrying out experimental research, by technological requirements of the environmental parameters and by the quality of the material used. However, the lower are the temperatures required for the air, and the greater are the limits of their modification in the summer, the more cumbersome are the air conditioning installations and the larger is the necessary surface for setting them up.

The requirements of temperature, air humidity and air velocity, as well as lighting and the level of carbon dioxide depend on the aim of the experiments and the plant species being studied.

The parameters for calculating air in the various areas of the phytotrons are brought together in Tables 4 and 5.

Table 5 shows that the most severe requirements for air parameters as well as for the variation limits of the parameters are those of the Odessa phytotron.

Table 4. - Limits of variations of air and lighting parameters in greenhouses and cabinets in existing phytotrons.

air conditioned area	Institut Plant Phys. Ac. Sc. URSS			Irkoutsk		
	T°C	RH %	E 10^3 lux	T°C	RH %	E 10^3 lux
greenhouses						
entire years	5 to 40	-		-	-	-
summer	-	-		10 to 50	40 to 90	-
winter	-	-		5 - 50	15 - 90	-
growth and	20 to 50	20 to 90		-	-	
refrigera-	15 - 40	20 - 90	until	10 to 50 (1)	40 to 90	
ting	0 - 20	50 - 90	100	5 - 50 (2)	15 - 90	
cabinets	0 - 30	50 - 90		- 20 - 50 (1)	35 - 90	20
	-	-	-	- 20 - 50 (2)	15 - 90	
	0 - 15	-	-	- 20 - 5	35 - 90	
	- 10 - 10	-	-	0 - 10	-	
	- 20 - 0	-	-	0 - 15	-	
	30 - 100	-	-	0 - 30	-	
	15 - 40	50 - 90	-	70	-	
	- 60 - 100	-	-	-	-	
	15 - 40	50 - 90	-	-	-	
	- 60 - 100	-	-	-	-	

(1) summer regimen ; (2) winter regimen .

Table 5. - Limits of variations of air and lighting parameters in greenhouses and cabinets in the phytotrons in construction or being planned.

air conditioned area	Odessa			Mironovka			Krasnodar - Oleaginous			Krasnodar - Rice		
	T°C	RH %	E 10^3 lux	T°C	RH %	E 10^3 lux	T°C	RH %	E 10^3 lux	T°C	RH %	E 10^3 lux
Greenhouses												
entire year	5 - 15	40 - 80	-	30 - 45	30 - 70	until	-	-	-	10 - 35	60 - 80	-
	15 - 30	40 - 80	-	15 - 30	60 - 90	30	-	-	-	-	-	-
	30 - 45	40 - 80	-	-	-		-	-	-	-	-	-
winter	-	-	-	20 - 30	60 - 80	20	-	-	-	-	-	-
summer :	>15	50 - 80		15 - 30	40 - 80		-	-	-	-	-	-
during day	15 - 20	70 - 80	until	-5 - +5	60 - 80	until	-	-	-	-	-	-
	15 - 30	70 - 50	20	-	-	40	-	-	-	-	-	-
	15 - 25	50 - 55		-	-		-	-	-	-	-	-
	30 - 45	40 - 30		-	-		-	-	-	-	-	-
night	20 - 45	70 - 40		-	-	20	-	-	-	-	-	-
autumn and	15 - 35	70 - 40		-	-		-	-	-	35	60	20
winter	5 - 20	60 - 80		3 - 5	60 - 80	20	-	-	-	-	-	-
autumn	15 - 35	70 - 40		-	-		-	-	-	-	-	-
	2 - 45	60 - 30		-	-		-	-	-	-	-	-
	10 - 45	40 - 30		-	-		-	-	-	-	-	-
autumn, winter and spring	-	-		-15 - +5	60 - 80		-	-	-	-	-	-
day	-	-		3 - 15	40 - 80		16 - 32	60 - 80	20	> 25	-	-
night	-	-		-	-		12 - 22	80 - 95	20	> 25	-	-
spring	-	-		20 - 30	60 - 80	20	-	-	-	15 - 35	80	20
Growth cabinets	-25 - +5	60 - 80		-	-	-	-10 - +15	60 - 80	32	-5 - +15	-	10
	-5 - +5	60 - 80		-5 - +15	50 - 80	20 - 50	-	-	-	5 - 10	60	20
	-5 - +5	30 - 80		-	-	-	0 - 30	60	56	-	-	-
	5 - 15	60 - 80	until	10 - 45	25 - 50	20 - 50	-	-	-	-	-	-
	15 - 30	60 - 80	50	15 - 30	50 - 80	20 - 50	12 - 40	20 - 80	56	15 - 40	25	20
	18 - 25	60 - 80		-	-	-	-	-	-	-	-	-
	15 - 30	40 - 50		-	-	-	-	-	-	15 - 40	80 - 90	20
	30 - 45	60 - 80		-	-	-	-	-	-	25 - 37	-	20
	-40 - +5	-		-	-	-	-	-	-	-	-	-
	-25 - +5	-		-	-	-	-	-	-	-	-	-
cabinets for seed conservation	5 - 15	60 - 80		-	-	-	-5	50	-	25	15	-
wind tunnels	10 - 45	10 - 50		25 - 40	15 - 20	20 - 50	-	-	-	30 - 40	25 - 35	20
	5 - 15	15 - 50	until	-	-	-	-	-	-	-	-	-
	15 - 30	15 - 50	50	-	-	-	-	-	-	-	-	-
	30 - 45	15 - 50		-	-	-	-	-	-	-	-	-
humid cabinets	15 - 25	100		-	-	-	-	-	-	> 25	100	20
vernalisation cabinets	15 - 25	-		-40 - +5	-	-	-	-	-	-	-	-
refrigerating cabinets	5 - 40	30 - 95		-	-	-	-	-	-	-	-	-
	10 - 35	60 - 80		-	-	-	-	-	-	-	-	-

This, probably, is reflected by the relative increase of the surface reserved for machinery - 59 % as well as by a greater consumption of heat, cold and electric energy per surface unit.

When establishing the technical conditions needed for planning very wide limits for environmental parameters are frequently chosen for certain rooms, in particular of air, which leads fatally to an increase in the price of the systems elaborated. In a series of cases and in order to diminish the prices of the air conditioning systems and other systems elaborated, it is interesting to distribute parameter variations in relatively narrow limits of intervals, where each ones fed by different systems for specialized growth chambers.

In the phytotrons being planned, it is necessary to take into account possible modifications of the character and methods of experimentation of future plants, to assure technological and planning flexibility, to create within reasonable limits surfaces reserved for growth chambers or rooms and to foresee the possible increase of the pipe system and the capacities of the supply system for water, heat, cold, gas and electricity.

Greenhouses and growth chambers must be fitted out in as much as possible with a standard industrial state and this within the installation complex for air conditioning, light and the means of automatic regulation.

2 - Greenhouses and their orientation in terms of cardinal points.

The construction of greenhouses must meet the following requirements :
. solidity : it must be sufficient to resist wind and the added loading of snow
. air and water tightness : to avoid the intake of unforeseen exterior air and water penetration in case of rain, or the installation of top water circulation
. no possible corrosion, in the case of high air humidity and raised temperatures
• technological "flexibility" : the possibility of modifying the installations for a series of plant cultures.

From a physiological and lighting technique viewpoint, the entire surface of greenhouses and all the plants cultivated must be lit uniformly by natural light during the day. If greenhouses are only used during the cold period of the year, a maximal penetration of solar energy is necessary for plant development. The same greenhouses must be oriented with glass towards the south, which, at the same time, favors a certain heat savings in the automn and in the spring, when the contribution of heat by solar radiations is still fairly important.

From a thermic point of view, it is important that the penetration of heat in the summer from solar radiations, and consequently, the capacity of the ventilation and air conditioning systems, the cold flow, the investments and expenses of cultivation be kept minimal.

Heat penetration from solar radiations were measured in the case of greenhouse orientation with a longitudinal East-West and North-South axis. Calculations have shown that during 24 hours two maxima for solar radiation penetration is observed.

In the two cases heat penetration through glass surfaces represents a large part of the total penetrations, and moreover, this part becomes greater if the latitude of the place where the greenhouse is found is low. The total heat penetrations through various greenhouse surfaces in a North-South and East-West orientation differ relatively little, as can be seen in Table 6.

Table 6 shows that in average latitudes (40-50°) the ratios between heat penetrations from solar radiations are practically uniformly equal for greenhouse orientations ; and in high latitudes (56-64°) there is a difference of 10-14 % and a less important heat penetration is observed in a North-South orientation ; also all other conditions being equal in high latitudes, from the point of view of heat penetration, it is preferable to have a longitudinal North-South greenhouse orientation and for average latitude both orientations are practically equivalent.

Table 6. - Ratio between global penetrations and calculated from solar radiations through greenhouse windows with various longitudinal axis orientations.

Ratio between heat penetrations Q — Q east-west / Q north-south	Geographical latitudes in degree			
	40	48	56	64
Maximum	0,98	1,04	1, 02	1,12
Calculated	1	0,99	1,10	1,14

Greenhouses must be placed as much as possible with the parallel longi tudinal axis at the wind axis, this diminishes exterior air penetration by infiltration through defects in the air tightness. To avoid this infiltration it is necessary to maintain in greenhouses, particularly those with an air conditioning system, a slight suppression. This can be obtained by an intake of air superior to its extraction in a ratio of 1-1,5 volume per hour.

3 - The microclimate in growth chambers.

a) - Distribution of lighting installations.

The microclimate of growth chambers depends in large part on energy distribution coming from artificial lighting sources ; the plan, for air distribution, the plants layout in the chambers, the air conditioning systems which assure the maintenance of air parameters.

Research concerning the rules which govern the distribution of heat penetration from luminous sources was carried out with three air conditioned growth chambers. In one of the cabinets there were two xenon lamps with rectilineal arc (DKCT-20) each of 20 KW, in the second 36 incandescent lamps with incorporated reflector, 3C-300 type, with a total power of 10,8 KW; and in the third, quartz iodine lamps (KI-1000) with a total power of 12 KW. The xenon and quartz iodine lamps (Fig. 1,2,3) were distributed in a space reserved for lumps and were cooled by exterior air ventilation, and the incandescent lamps were partially immersed in a water filter and cooled by a draft and running water which penetrates in the water filter with evacuation by cement pipes.

Table 7 gives the conditions for the observations made.

The research results are represented in graph form in Fig. 1,2,3. As can be seen in the graphs, when the quantity of water is increased, let in on the glass of the water filter, the quantity of energy retained by this filter increases and the quantity of energy which penetrates into the cabinets and which is absorbed by the air that blows on the lamps, decreases. The energy distribution of the lamps depends as well on the quantity of air cooling of the lamps. When it increases there is a decrease of energy trapped by the water filter, and an increase in the quantity of energy absorbed by the air in the chamber and by that of the cooling of the lamps.

Table 7. - The conditions for carrying out experimental research on energy distribution from light sources.

Indexes	Light sources		
	Xenon lamps	Incandescent lamps with reflector	Quartz-iodine lamps
Air consumption m^3/hour : . in growth chamber . for lamps	970 - 980 7000 - 9600	1600 9500 - 10000	1400 - 1600 10000 - 11000
Water flow through filter, 1/hour	190 - 400	190 - 400	190 - 400
Initial air temperature (°C) . in growth chamber . in lamps	20 - 21 26 - 28	18 30 - 34	22 27 - 30
Initial water temperature °C	18 - 21	18 - 20	18 - 20

With respect to xenon lamps, lamps with reflector send more energy in the experimental part (21-25 % versus 5-8 %) gives more to the water filter (20-40 % versus 10-20 %) and less to the cooling air of the lamps (30-60 % versus 75-80 %). The energy distributions noted in the rooms with lamps with reflector are explained by the fact that their bulbs are directly immersed in water. The relative energy distribution with quartz-iodine lamps is the same as with xenon lamps, but the power installed with the quartz-iodine lamps is 3-4 times lower than that with xenon lamps. Consequently, in the growth chambers equipped with quartz-iodine lamps, the thermic overload on refrigeration equipment is 3-4 times less than in growth chambers with xenon lamps or with incandescent lamps with reflector.

In air conditioning techniques, the process for changing air parameters is characterized generally by the temperature -humidity ratio. However, on account of the impossibility for exactly determining the percentage of air humidity, instead of a temperature-humidity ratio, we have calculated the coefficient A = tc. In this case tc and I correspond to the differences of dry temperature and I air enthalpy before and after passing into the growth chamber or in the lamp compartment.

The ratio of the coefficient A to the quantity of air and of water was determined in the growth chamber with xenon lamps. In the experimental part of the growth chamber a culture using tomatoes as the experimental plant was set up.

Figure 4 reproduces the existing ratio between the coefficient A and the quantity of water let in on the glass of the filter. As shown in this figure, with an increase on the quantity of water and blown air, the process which unfolds in the volume of lamps comes close to the process which unfolds in the case of constant water percentage A = 4,16.

In the experimental section of the growth chamber the influence of the quantity of air which cools the lamps on the A value is very weak, and one can say with a sufficient amount of approximation, that within the limits of our experiences A depends only on the water consumption which flow away on the glass of the filter. The character of the variation of A indicates that with a decrease in the quantity of water that passes through the water filter, there is an increase in the plants' transpiration.

The characteristic of the variations established for A is in perfect coordination with plant physiology. As a matter of fact, with a decrease in the water that is carried on the glass of the filter, there is an increase in the quantity of energy which penetrates into the experimental part, that provokes an activation of plants' respiration and, consequently, a more active transpiration.

In the experimental areas of the growth chambers, levels of the light, thermic radiations and PAR (photosynthetic active radiation) were measured directly against the water filter and at distances of 50 cm and 1 meter.

An unequal distribution of the various radiations on the surface of the growth chamber was noted. This inequality varies within the limits of 5 to 60 % in terms of the kind of rays and of the distance with respect to the glass of the water filter. Moreover, with distance this variation decreases. This unequal distribution may be explained not only by a lack of adequate distribution of the lamps on the surface of the chamber, but also by the quality of the lamps and their different length of use. To be more explicit, the variations of luminous radiations, thermic and PAR, are illustrated in Figures 5, 6 and 7, where the localized experimental values of lamp radiations are reproduced, according to levels of 0-50 cm and 1 m of the glass of the water filter and in 3 different positions with respect to the side of the growth chamber (x).

A comparison of research results on radiation conditions of growth chambers with xenon lamps and incandescent reflector lamps show that an xenon installation is 4 times more powerful than that with incandescent reflector lamps, however the quantity of energy which penetrates into the experimental section from incandescent reflector lamps is 4 times superior to that of xenon lamps. In this case the thermic and PAR radiation values remain practically the same and the quantity of the light which penetrates into the experimental section of the growth chamber with incandescent reflector lamps is two times less than for the xenon lamps. It should be particularly noted that the intensity of the PAR radiations in the growth chambers with quartz-iodine lamps is superior to that with incandescent reflector lamps or to that with xenon lamps. Thus, the quartz-iodine lamps are effective as regards PAR radiations and require less power and need less of a cooling output by the refrigerating units.

b) - Coefficients of thermic transmission of air by the growth chamber walls.

Growth chambers are characterized by important exchanges of air : 100 - 300 times per hour. For certain values of convection coefficients of thermic exchanges, the hydrodynamic state of air movement can be determined.

The search for convective thermic exchange coefficients in growth chambers were carried out for the two most common ventilation scheme : by air flow from bottom to top and from top to bottom.

The thermic exchange coefficients were determined for two temperature fields, taken by means of a 4 mirror interferometer with a diameter for a scope of action of 225 ± 5 mm in the "infinite" band widths.

It was observed that in the case of bottom to top air displacement the thermic exchange coefficients at ground and ceiling level decrease in the sense of a diffusion of the entrance current. Instead of a rupture of the current with the ground, as well as at the place where it meets the ceiling, the convective thermic exchange coefficients have practically the same value. The thermic exchange coefficients of the lateral walls have minimal values at equal distance to the blowing and output slots.

In the case of air movements from top to bottom the character of the variations of thermic exchange coefficients is identical in the sense of a diffusion of the blowing current. In, the two schemes for air exchange in the same positions and outputs, the thermic exchange coefficients are identical within the limits of precision.

A general equation giving localized thermic exchange coefficients for lateral walls was able to be set up in the two diagrams for air exchange :

$$Nu = 0,84\ (Re/Yr)\ 0,6\ [(0,742\ lido)^2 - 1,321/do + 62,551.10^{-3}$$

with $(0,14 < Re/Yr < 1,8)$ and $(74 < 1/do < 104)$

Nu, Re and Yr are Nusselt, Reynolds and Grassgof identity criteria

By generalizing the existing link for establishing thermic exchange coefficients of convection of a horizontal surface which arrives at the extraction slot one can write :

$$Nu = 0,78 . Re^{0,8} ' (lido)^{-2,4} . 10^{3}$$

with (80 <Re Lc 550) and (55 <1/do < 70)

The average convective thermic exchange coefficients may be determined by means of the following formulas :

. for the entire lateral wall : Nu_m 4, 94 (Re/Yr) 0, 6

. for the entire horizontal surface, next to the extraction slot : $Nu_m = 0,06 . Re^{0,8}$

c) - Air distribution in growth chambers. Natural observations in the chamber.

The following schematic determinations for air distribution were carried out (Fig. 8)

1. From top to bottom : air inlet passing through two 245 x 45 mm. screens set up on the upper part of the lateral wall and recovered up again through a 240 x 300 mm opening at the back, near the same wall.
2. From bottom to top : air inlet through two 25 x 250 mm regular intake slots of cross section set up in the bottom, through 30 mm high and 140 mm wide slots.
3. From bottom to top : air inlet by four perforated intakes from 2 50 x 2 50 mm of cross section and 1 500 mm wide placed at the bottom of the chamber at a a distance of 550 mm between the intake axes. The upper intake walls are perforated panels of the following dimensions : 250 x 1500 mm with openings of a 10 mm diameter and a pitch of 30 mm. The coefficient of perforation section of the panel is equal to 0,084. The air exhaust in diagrams 2 and 3 is done through 30 x 1400 mm slots.
4. From top to bottom : air inlet by two regular diffusion tubes in the upper part with extraction by an opening in the middle of the torso wall (500 x 420 mm screen).
5. From top to bottom : air inlet by two regular diffusion holes in the upper part (6 x 300 mm slots) and air extraction by two regular pickup tubes (20 x 300 mm slots) in the lower part. These plans were tested by means of an interferometer (3).

Figure 8 shows that in all conditions the current moves about horizontally until it meets the torso end wall of the chamber, without deviating from its initial direction. The velocity profiles in the current were practically symmetrical with respect to the axis of the current.

In the plant area with empty beds the air temperature increases practically uniformly with height in the chamber. In the case of shelves occupied by plants the difference between temperatures in the upper and lower areas remain practically the same as in the case of empty shelves, however the temperatures above and below the empty shelves are distinctly different. Moreover, within the limits of each area the temperature varies little in height.

The character of air velocity distribution in the plant area is practically the same for all conditions : decrease of air velocity at the level of the shelves and increase of velocity as it approaches the bottom and the ceiling. Strong velocity variations were observed in the vertical sections far from the regulating screens. In the case of closed shelves the velocity in the plant area decreases slightly. The temperature of the extracted air is in all conditions inferior to the air temperature in the plant area, which confirms the poor position of the extraction opening ; through which the non-treated air coming from the opposite current is evacuated.

d) - Air conditioning systems of growth chambers.

The air parameters of the chamber (T, HR, I, d) can be illustrated on the diagram i-d in the form of 6 areas (Fig. 9) and in universal chambers in the form of an area which can be extended to all diagrams. The parameters which are found within the limits of area VI, are characteristic for refrigeration chambers with machines on several levels and for this reason they will not be examined.

The classification reproduced in Fig. 10 takes up the majority of air conditioning systems used and studied (air conditioning systems - ACS). The particularity of autonomous ACS with an autonomous refrigeration unit resides in the greater possibility for individual regulation of the air parameters in each chamber, the difficulty lying in its operation due to the decentralization of the preparation and the cooling with respect to the rest of the Phytotron. This inconvenience does not exist in the non autonomous ACS, fed by centralized sources of heat and cold, but on the other hand, it is less flexible in the various chambers.

In production in several areas combined ACS can be used. For example, to maintain parameters in the areas I-1V, systems of valve irrigation can be adapted on the ACS, working in polytropic cooling and drying conditions (ACS PS.P) or in air surface cooler with refrigerating brain or direct evaporator (ACS-P-A-S or ACS-P-A-d). In this case, the valve chamber must operate within the parameters of areas I and II and the air/surface cooler within the parameters in areas III and IV.

The advantage of the systems noted above resides in using air conditioners of standard industrial manufacture. However, in the systems used sometimes it is necessary to use non-standard material (e. g. refrigerators with direct evaporator, defrosting equipment, etc.).

The main drawbacks of the ACS examined lie in : the impossibility to maintain parameters in area V ; the presence of a secondary heater and consequently additional necessity for cold, necessity for using refrigerating machinary in air heating operations for drying in the case of $Y_e < Y_k$; dc > dk.

Figure II represents a new ACS (ACS-P-A-S-3) which ensures parameters in all of the areas I-IV. The exterior air, after filtration, is dried, cooled and mixed with recirculating air; the mixture of exterior and recirculating air is cooled or heated by an exchanger for each chamber, if necessary it is humidified. The intake of part of the load by the exchanger for each chamber makes it possible to decrease the air refrigerating dimensions, working in feast conditions as well as cold and heating expenditures and at the same time to decrease the period for the secondary heating of cooled air.

In order to decrease refrigerating loads on the ACS it is logical to partially eliminate heat from the growth chambers by means of a radiative cooling system placed in the walls of the chambers.

The aerodynamic resistance of a chamber with plastic contact does not exceed 15 kilograms/m^2 for an air velocity of 8-10 m/sec.

On Fig. 12 can be seen the main plans of an ACS, working on a lithium chloride solution (ACS-U-Sr-ab-I). This system makes it possible to maintain the parameters in areas I-V (in other words to guarantee good operation in universal growth chambers). The exterior air is in contact with a lithium chloride solution in a plastic contact chamber (4,2 ; 4, 3). In case of a need to maintain humidity under 10 %, the system is completed by a secondary air reheater (3). The process of second reheating is figured by dashed lines.

A lithium chloride solution at the bottom of the plastic chamber 28 passes by gravitation into tank 23 where pump 24 carries it in the summer into regenerator 29 after counter current reheating in solution exchanger 26. The solution is regenerated in another plastic contact chamber 29 by desorption method at 50-60°C. Generally, for desorption it is admitted 10-15 % of the total quantity of the solution. In winter the concentration of the solution is regulated by the addition of tap water. The regenerated solution flows out of the regenerator by gravitation into a tank where a pump, carries it towards the air conditioner, previously cooled to the desired temperature in counter current exchanger 27. In the winter, the solution passes from the tank into the air conditioner through exchanger 27, where it is heated to the necessary temperature.

The ACS-U-Sr-ab diagram makes it possible to treat the air in temperature and humidity, to regulate its parameters by means of variation of temperature and concentration of the solution, to decrease cold consumption and to decrease electric energy needs to displace the air. The lithium chloride solution in addition has bactericidal properties. To use this system it is necessary to industrially manufacture the contact apparatus.

The drawback of this system lies in the very corrosive action of the lithium chloride solution. However, the use of potassium bichromate in its role as an inhibitor in quantities of 1 % by volume makes it possible to reduce the corrosive action of the lithium chloride' solution by about 15 times and makes its use possible for chambers with walls of ordinary steel (4, 3).

Table 8. - Heat, cold and electric energy expenditures in various air conditioning systems for growth chambers

Indexes	Unit of measure	ACS-P-A-S-2	ACS-P-A-S-3	ACS-U-Sr-ad-1	ACS-U-Sr-ad
Heat expenditure of which :	Kcal/hour/%	21600/100		19000/88	
. for air conditioning	Kcal/h	21600	-	-	-
. for regeneration of sorbent	Kcal/h	-	-	1900	-
Cold expenditure of which :	Kcal/h/%	34500/100	13800/40	31300/91	14420/42
. for air conditioning	Kcal/h	34500	13800	13800	12900
. for cooling the sor- bent after regene- ration	Kcal/h	-	-	17500	1520
Electricity expenditure of which :	KW/h/100	13,2/100	9,45/71,5	9,92/75	1902/145
. for preparation of cold	KW/h	9,5	4,33	5,92	3,62
. for fans and pumps	KW/h	2,7	3,15	2,5	3,4
. for pumps	KW/h	1	1	1,5	1
. for reheating of the sorbent for regeneration	KW/h	-	-	-	11

Figure 13 gives the block diagram for the ACS-U-Sr-ad units which keeps the parameters in zones I-IV. These ACS can be used as well in universal growth chambers. The exterior air in drying conditions is treated in an absorber with a periodic or permanent action (24 or 25) and then, it is mixed with the recycling air and cooled to the temperature desired (without dehydration) in refrigerator 4. Apparatus with periodic action automatically pass from conditions of absorption to conditions of reactivation. In apparatus with a permanent action, about 75 % of the absorbant is again found in permanence in air currents during dessication and extracts the humidity, and about 25 % of the absorbant while going through the dry air current, giving back the humidity and in this way reestablishing its faculty for absorption. To reactivate, the absorbent is heated in such a way that the vapor pressure of the humidity absorbed be superior to a partial water vapor pressure in the air which flows through the reactor. The temperature of reactivation for silicagel must not exceed 150°C. In the pores of the cooled absorbent after its reactivation the water vapor pressure is inferior to a partial water vapor pressure in the air.

An additional quality of this ACS unit lies in the lower expenditure of cold, due to the absence of a second reheating of the dried air. The disadvantages of these systems lie in the need to heat the absorbent by high pressure vapor, or by electricity, as well as in the strong aerodynamic resistance of the dryers.

To be able to judge the energy expenditures of the various ACS in Table 8 are gathered the results of calculations made in the particular case of maintaining in the growth chamber a temperature TB = 20°C, a relative humidity of

RH_B = 25 % for the parameters of the exterior air of TH = 30°C ; RHH = 45 To.

The global quantity of air was taken equal to 5000 m^3/H, the need for exterior air equal to 500 m^3/H (10 %). This table shows that the lowest expenditures of heat correspond to the systems ACS-P-A-S-3 and ACS-U-A-ad ; the lowest expenditures of cold with ACS-P-A-S-3 and energy with ACS-P-A-S-3 and ACS-U-Sr-ab of course for other values the ratios can be different.

Conclusion.

The data presented in this article and the results of the special experiments done can be used as a basis of reference in system projects which ensure the microclimate in the Phytotrons and in growth chambers which are placed at the disposal of laboratories.

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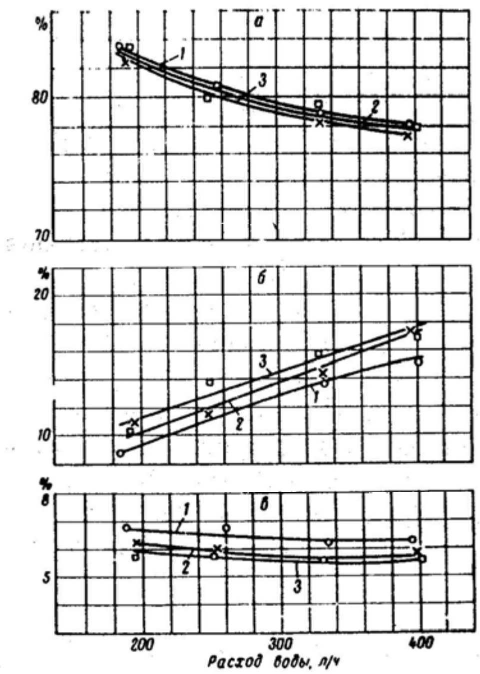

Fig. 1 - Distribution of heat production by xenon lamps in a plant growth chamber. a. Lamps - b. Water filter - c. Experimental growth chamber. Air consumption for the lamps : 1-9600 m^3/H - 2-8000 m^3/H - 3-7000 m^3/H

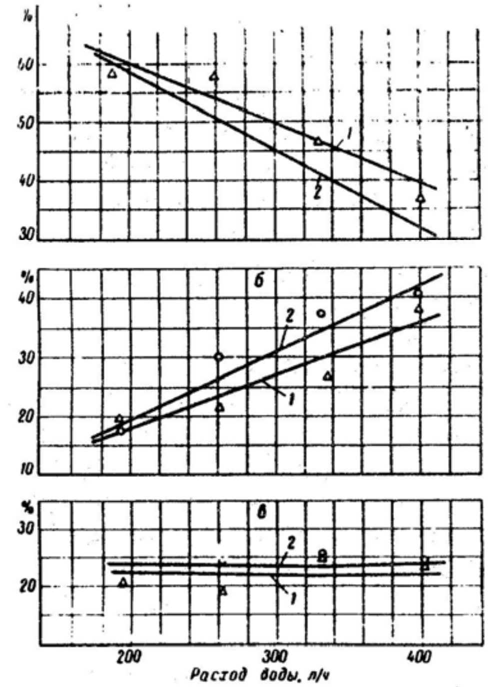

Fig. 2 - Distribution of heat production by incandescent reflector lamps in a plant growth chamber. a. Lamps - b. Water filter - c. Experimental growth chamber - Air consumption for lamps : 1-9500 m^3/H - 2-1000 m^3/H.

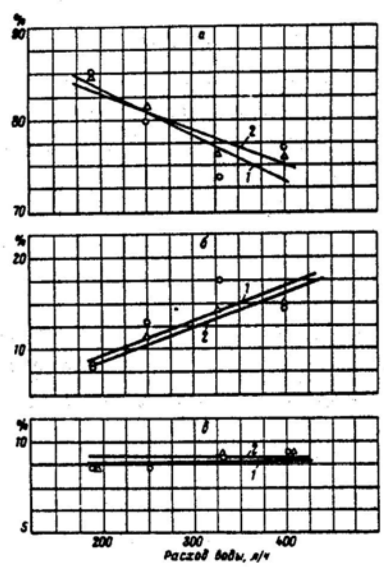

Fig. 3 - Distribution of heat production by quartz-iodine lamps in a plant growth chamber. a. Lamps - b. Water filter - c. Experimental growth chamber. Air consumption for the lamps : 1-11.000 m^3/H - 2 - 10.000 m^3/H.

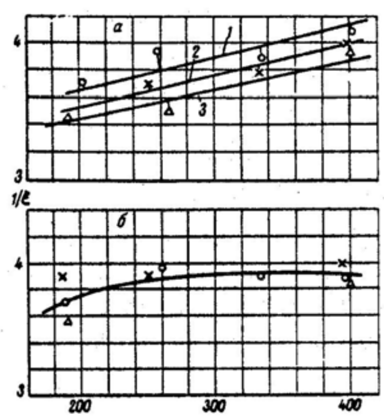

Fig. 4 - Relation between coefficient A, water quantity and air consumption for cooling. a. Lamps - 1. Air consumption : 9600 m^3/H - 2. Air consumption 8000 m^3/H - 3. Air consumption 7000 m^3/H - b. Experimental growth chamber.

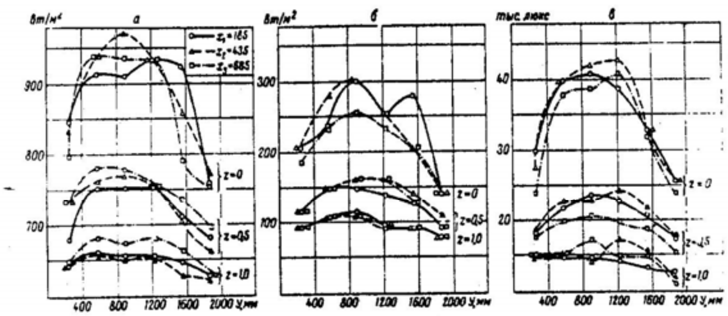

Fig. 5 - Local radiations values at various levels in a plant growth chamber equipped with xenon lamps.
a. Thermic radiation - b. Luminous radiation - c. PAR

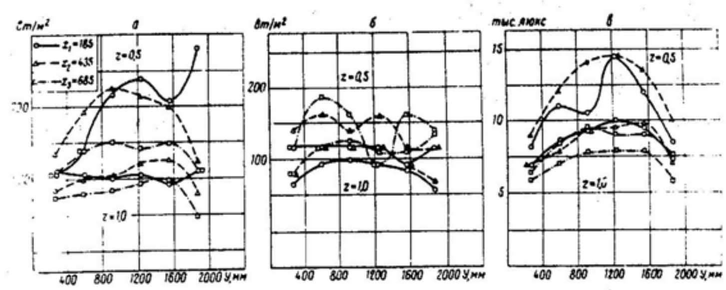

Fig. 6 - Local radiation values at various levels in a plant growth chamber equipped with incandescent reflector lamps.
a. Thermic radiation - b. PAR - c. Luminous radiation.

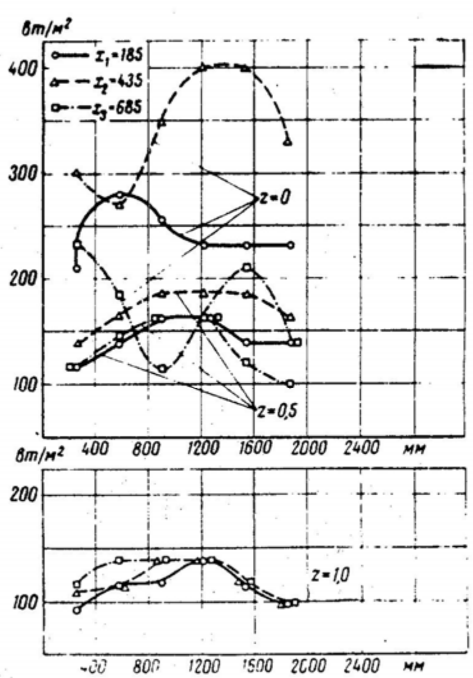

Fig. 7

Local PAR values at various levels in a plant growth chamber equipped with quartz-iodine lamps.

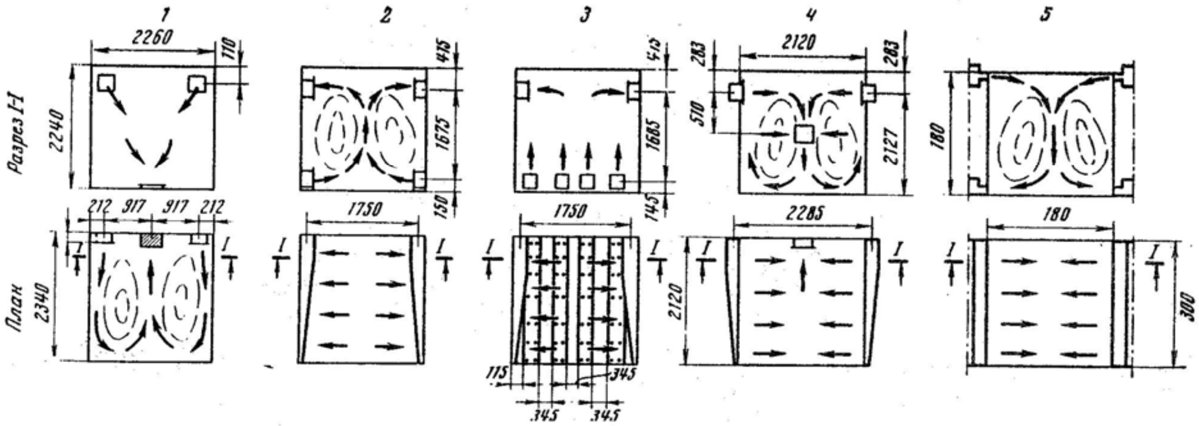

Fig. 8 - Diagram for air distribution in a plant growth chamber.

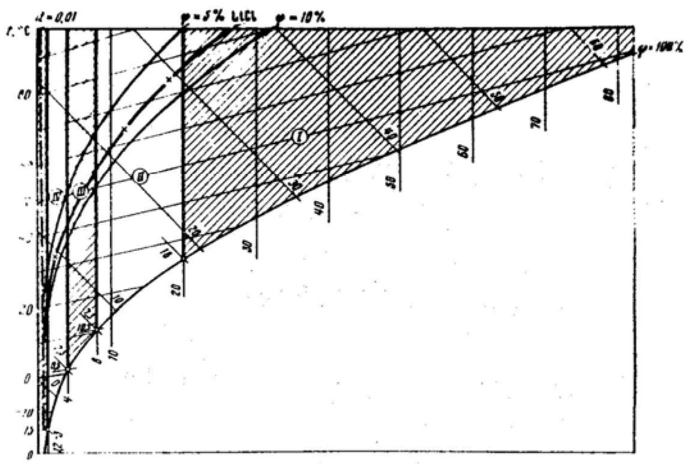

Fig. 9 - Work zones in specialized plant growth chambers in Phytotrons.
d. 0, 01. Limits for use of ACS with air drying by silicagel (or lithium chloride in the presence of secondary heating). LiCl. Limits for use of ACS with air treatment by lithium chloride without a second reheating. I-IV. Zones with air parameter variations.

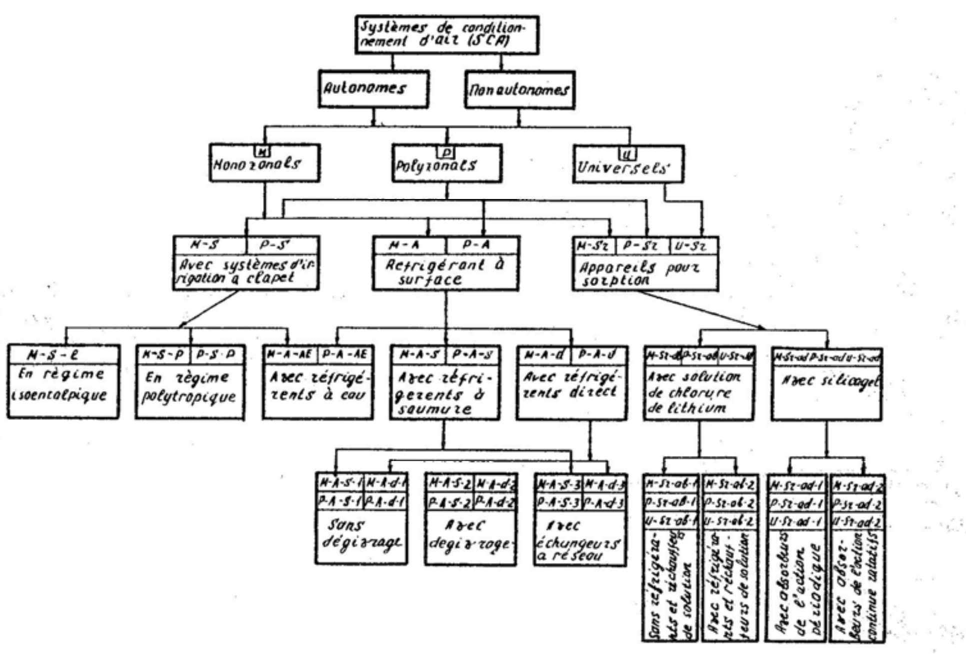

Fig. 10 - Classifying air conditioning systems in plant growth chambers.

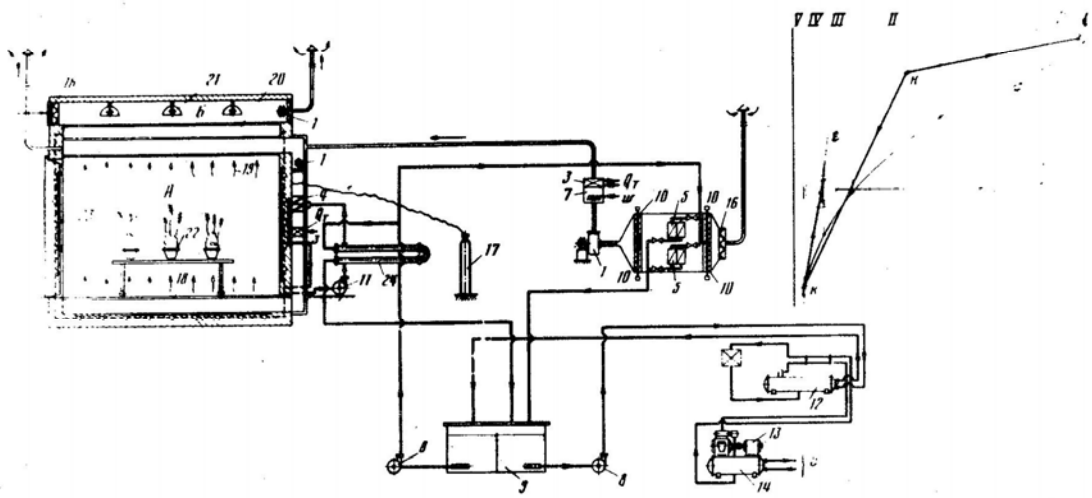

Fig. 11 - Diagram of the ACS covering several zones with polytropic exterior air cooling by a negative T° brine followed by cooling of a mixture of exterior air and recirculating air in a refrigerating network (ACS-P-A-S-3) for each room.

Explanation of indexes :

a. ACS in isoanthalpic humidification (ACS-Sr- e) - b. ACS with polytropic cooling in an apparatus fed by cold water at a T° higher than 6°C (ACS-P-S-d) - c. ACS with polytropic cooling in an apparatus fed by brine at a T° higher than 0°C (ACS-P-A-b) - d. ACS with polytropic cooling in an apparatus fed by brine at a T° lower than 0°C (ACS-P-A-sr).
A. Volume of the air conditioned room - B. Volume with lamps - H. Exterior air parameters - C. Parameters of a mixture of exterior and recirculating air - K. Air parameters after treatment in an exchanger - n. Inlet air parameters - b. Outlet air parameters - p. Air parameters after regeneration - Q_T. Heat intake from an exterior source - W. Water intake in "fog" equipment - L. Piping to heat exchanger - I. Fan with motor - 2. Air reheater from 1rst reheating - 3. Air reheater from 2nd reheating - 4. Air cooler - 5. Air cooler with periodic stoppage for defrosting - 6. Irrigation growth chamber - 7. "Fog" humidifying equipment - 8. Pump with motor for brine adduction - 9. Brine tank - 10. Air valve - 11. Pumps with motor for water adduction - 12. Evaporator for cold unit - 13. Compressor with motor for cold unit - 14. Water cooling condensor of cold unit (the exchanger is not shown) - 15. Water tank - 16. Air filter - 17. Carbon dioxide feeding - 18. Perforated floor - 19. Air inlet opening - 20. Transparent ceiling with distilled water - 21. Lighting lamps - 22. Objects of experiments - 23. Lighting cooling system - 24. Water coolers.

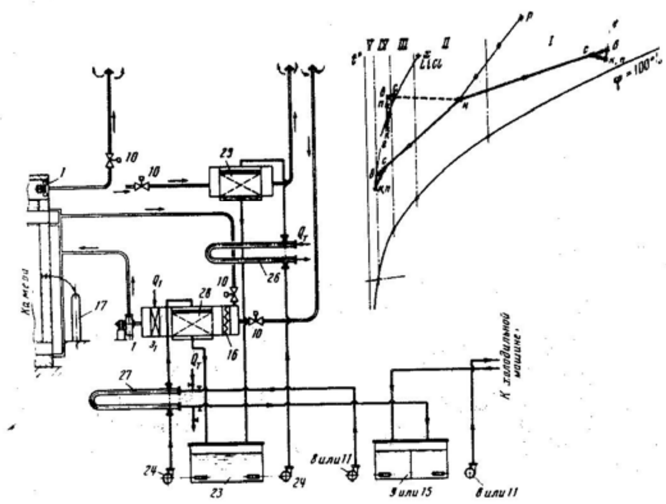

Fig. 12 - Diagram for a universal ACS with air treatment by a lithium chloride solution (ACS-U-ab-I).
Numbers 1-22 correspond to those of Fig. 11. 22.24 : Pumps and motors for brine - 26. Brine reheater - 27. Brine cooler - 28. Plastic room for air treatment - 29. Plastic room for brine concentration.

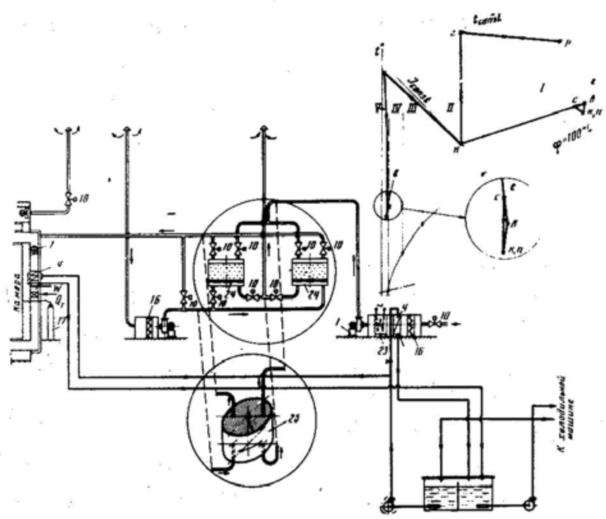

Fig. 13 - Diagram of a universal ACS with air dessication by silicagel (ACS-U-S-ad).
+ with periodic action adsorbants (ACS-U-S-ad-I) - ++ with continuous action rotating adsorbants.
Numbers 1-15 correspond to those of Fig. 11 - 16.22, see Fig. 12 -
23. Electric air reheater - 24. Periodic action adsorbant - 25. Continuous action rotative adsorber.

VII - BIOENERGETIC ASPECTS OF CONTROLLING AGROECOSYSTEMS PRODUCTIVITY

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The way to meet the ever-growing demand for food and organic raw materials lies possibly in a sharp increase of plants production under the natural conditions or in the plants highly productive breeding under the controlled conditions fortified by the use of artificial sources of optic radiation. The second way implies heavy consumption of energy and can be justified only in case of cheap energy available together with the sources of a highly sensitive reaction to photosynthesis. The first way evidently deserves maximum attention. High hopes for a further increase of the agricultural production rest with the technologies based on utilization of mathematical modelling and programming of the crop yield. However, comprehensive dynamic models of production processes are difficult to obtain. It is expedient to use simple models based on a systematic analysis and employing a limited number of essential parameters. A systematic approach helps to distinguish three major systems for plants viability : metabolism, energy exchange and controlling or information processes. The systems of metabolism and information processes may be partially or completely closed. The energy exchange system is unidirectional : if the electromagnetic energy of radiation is not assimilated in the process of photosynthesis it irrevocably deteriorates into thermal energy. Controlling of or provision for the conditions of plants energy exchange is the most complicated and expensive task. This is evident from the experience of plants breeding in hot-houses, phytochambers, phytotrons when a yielding capacity several times higher than under natural conditions is achieved.

The cost of crops grown under artificial conditions is high due to large expenses on keeping the necessary level of irradiation for providing productive photosynthesis and temperature. Consequently, more attention should be paid to bioenergetic aspects of controlling agroecosystems productivity. The lame conclusion may be drawn from the main laws of alive nature distinguishing it from dead matter. Photosynthesis of the plants is the main natural process deferring continuous universal growth of entropy. The capacity to slow down entropy growth arose in the alive organisms due to accumulation and use of information, constant piling of which increases the complexity and variability of structures and functions of alive organisms and their communities. Growth of information delays growth of entropy. The capacity of alive organisms to defer entropy growth is one of the important "objectives" of alive nature. This capacity may be considered a dielectic opposite of the law of universal entropy growth in the non-alive nature. Biogeocenosis, agroecosystem, sowing, etc. should be viewed as examples of an automatic system with an informational purpose program, worked out in the process of evolution according to the definite laws imposed by the environment variations and tuned to the maximum utilization of free energy. This purposeful adaptability of alive systems should be presented in dynamic and static plans. The alive systems respond with protective reactions to the constantly changing conditions of the environment and use the accumulated data which allows, in a statistical sense, to envisage further possible prolonged variations in the environment. For the photosynthetizing organisms, free energy is represented by the photosynthetically effective energy of optical radiation, and for heterotrophic organism by the chemical energy of organic matter. Production of various products and organic raw materials may be viewed, in this context, as a bioenergetic problem.

While analyzing agroecosystems it is necessary to isolate the energy exchange system. Its main process is photosynthesis, and its principal input is electromagnetic energy of optical radiation. The system discharges mainly the energy of chemical bonds of newly-created organic matter. Under natural conditions the plant energy efficiency does not exceed 3 %, i. E. the output-to-input ratio in the system equals 0.03. To explain a possible increase of the output one must know the maximum photosynthetical efficiency of the complex solar radiation. The author has earlier developed methods for determining this value. For the position of the sun within 10-65° it constitutes 16-24 %. Taking into account probable energy consumption for plants breathing and limitations imposed by the imperfection of crops as photosynthetizing systems, as well as by the environmental factors deviation from the optimum values, the actual energy efficiency of plants under natural conditions may be estimated at 8-10 %.

In the central and southern zones of the USSR the plants yield can be substantially increased through elimination or, at least, reduction of the day depression of photosynthesis, that was earlier attributed to inner physiological rhythms of the plants. The analysis of the data of the round-the -clock process of photosynthesis in different climatic zones and at different stages of the plant growing period showed the energy origin of the day depression. Clearly defined optimum temperature of photosynthesis were also exposed.

The important controlling principle of production processes in the agroecosystems lies in the striving for the improvement of plants energy exchange with the environment to increase their bioenergetic efficiency and to better use free energy for photosynthesis. Inflow of free energy to the plants can be calculated with the help of a photoreceiver (a pickup) with a spectral sensitivity similar to the spectrum of the photosynthesis action. Thermal action of the radiation on the plants can be calculated through a pickup with a spectral sensitivity corresponding to the spectrum of the radiation thermal action. A considerable increase of the yield of different crop varieties in the central and southern zones can be reached through the use of cooling sprinkling techniques coordinated with the inflow of the solar energy and temperature on the basis of the optimum temperatures of photosynthesis. In eliminating the photosynthetical depression and drawing the temperature of the plant leaves nearer to the optimum temperature of photosynthesis it is possible to raise the energy efficiency of the plants 1.5-2 times. Several workers managed to increase the yield of cabbage, potato, beetroot and tea-leaves 1.3-1.9 times using intermittent sprinkling in the field. A considerable increase of the crop production can be achieved through purposeful formation of sowing and planting that would diminish the photosynthesis depression. The principles of such a formation are also considered.

While explaining the operating reactions in agroecosystems which provide improvement of the plants energy exchange and rise of their efficiency, it is necessary to take optical radiation of the plants for the main factor and coordinate all other factors with it. It is also necessary to secure such water regime of the plants that would minimize energy loss for transpiration and would keep the temperature of the plants leaves close to the optimum temperature of photosynthesis. It is desirable to form sowing and planting of the crops inclined to suffer from the photosynthesis depression so that in the morning and evening hours direct sun rays could hit the largest area of the leaves, while at noon a maximum mutual shading of the leaves would be provided. For a more accurate regionalization it is necessary to set a bioenergetic for each climatic zone. The potential is the value of total inflow of photosynthetically effective energy fit for photosynthesis on the basis of the thermal regime. Simultaneously with the increase of the total energy efficiency of the plants one should try to achieve a higher ratio of the useful product to the biological one.

At present active research is required in the field of the plants bioenergetic characteristics and zonal agroclimatic peculiarities connected with them.

Editor's Note.

This note is a summary, sent to us by the author from another longer study published in the book "Principles of controlling production processes in agroecosystems", Ed. Nauka, Moscow, 1976.

"VIII - ON OPTIMAL RADIATION REGIME FOR PLANTS IN LIGHT CULTURES

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Light is a major environmental factor in obtaining high crops of light cultures (1, 3, 4). The requirement of plants for light is known to be different at different stages of their growth and development. Therefore the necessity for rational distribution of light during growth acquires great significance. With a change in irradiance the adaptation of plants to a new environment is taking place resulting in a change in crop productivity.

The present paper deals with the results of the experiment which was aimed at establishing the relationship between productivity of wheat crops and changing irradiance, The data obtained allowed us to simulate the productivity of wheat crops grown at optimal irradiance.

Materials and methods.

Studies on the response of a plant's photosynthesis rate to changes in irradiance were carried out with club wheat 232 of two ages : 7-13 and 27-33-day plants. Before the start of the experiment the wheat crops were grown for 7 to 13 or 27 to 33 days at light intensities of 40-60 Wm^{-2} of PhAR (photosynthetically active radiation). Then each age group was transferred to a phytotron where for 5-7 days the plants were continuously exposed to different irradiances (40 to 400 Wm^{-2} of PhAR). The environmental parameters in the phytotron were as follows : air temperature 22-25°C, air humidity 50-60 %, CO2 concentration 0,5-0,8 %. The crops were grown under hydroponic conditions, with ceramsit as a substrate, and Knop solution as a nutrient medium. Light sources were xenon lamps DKsTV-6000.

Results and discussion.

The process of photosynthetic adaptation of the wheat crops to different irradiances affects the subsequent response of the plants' gas exchange rates to these changes in irradiance. In order to estimate the productivity of a wheat crop grown at different irradiances one should take into account adaptation of plants to a new environment.

Fig. 1 shows the dependence of gas exchange rates (curve I) and dark respiration rates (curve 3) of 33-day wheat crops, and of gas exchange rates of 13-day crops (curve 2) upon different irradiances to which the plants had been adapted. The wheat crops grown at low irradiance (40 to 110 Wm^{-2}) showed a linear increase in gas exchange rates after the transfer to higher irradiance (110 to 130 Wm^{-2}). However the wheat crop receiving even higher irradiance s during growth showed a non-linear dependence of gas-exchange rates on light intensity. Maximum gas exchange of young (13-day) plants was observed at 120 to 130 Wm^{-2}, and that of old plants at 170 to 200 Wm^{-2}. These results are in good agreement with the data obtained by A. I. Shulgin (6) and N. N. Protasova (5). Both dark respiration rate and photosynthesis rate initially increase with increasing irradiance and then decline. Maximum dark respiration rate of the crops is observed at higher irradiances than maximum photosynthesis rate.

The plants' gas exchange rates change with changing irradiance in the following manner. Shortly after a change in irradiance gas exchange rates change as shown by the photosynthesis light curve. Later in the process of adaptation to a new environment the plants moved from high irradiance to low irradiance have higher gas exchange rates than those moved from low irradiance to high irradiance. Similar response of a plant's photosynthesis rate to high irradiance was observed also by Steeman-Nielsen (7).

Studies on the, productivity of wheat crops grown at changing irradiance will allow one to calculate the amount of biomass accumulated by the crop during growth. To calculate the productivity of the wheat crops use was made of a simple mathematical model for simulating a production process of the wheat crops. Regression equations which describe the above relationships were taken as a basis of the model. Fig. 2 represents the computation scheme for simulating productivity of the crop exposed to optimal irradiance. The amount of PhAR absorbed by the crop depends on the leaf area index (L). The amount of absorbed PhAR (Ep) and coefficient (A) which defines the efficiency of absorbed PhAR utilization for the crop are responsible for the plants' gas exchange rates (F). The amount of the biomass increment (M) was calculated by the sum of gas exchange rates measured at different times multiplied by the proportionality coefficient (C). Daily calculations of possible gas exchange rates of the wheat crops (Fa) were done, adaptation of plants to a new environment being taken into account.

In accordance with the criteria chosen (Kp) optimal radiation regime for plants for the next time interval was determined. In this way optimal radiation regime for the crops was adjusted throughout the vegetation period.

Fig. 3 shows calculated curves for the amount of dry biomass accumulated by the wheat crop grown at optimal irradiances. There is a good agreement between the experimental (4) and calculated (2) curves for the amount of accumulated biomass when the plants are exposed to about equal irradiance s.

Thus, to determine optimal radiation regime for plants one should take into account adaptation of plants to a new environment. Calculation of optimal radiation regime which will allow one to obtain high crops can be done with a mathematical model in which the parameters that characterize productivity of crops during growth are taken as a basis (see Fig. 2). These parameters can be determined from experiments for a given plant in a given environment.

Studies on the effect of changing irradiance on productivity of crops are of great importance for industrial growing of light cultures, and phytotrons in such studies can be widely used.

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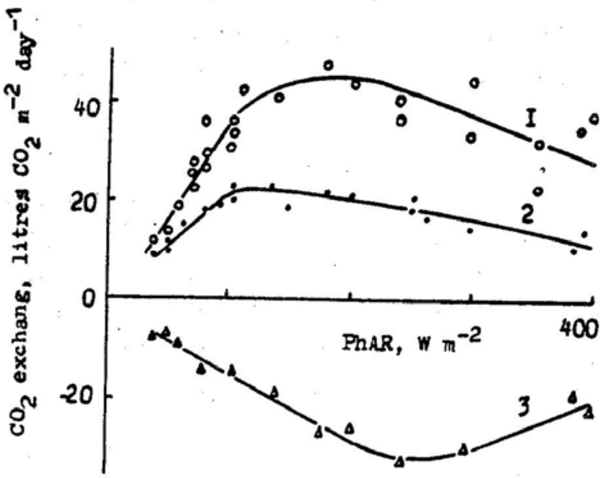

Fig. 1 - The dependence of photosynthesis and dark respiration rates on irradiance. Curves : I - gas-exchange rate of 33-day crops ; 2 - dark respiration rate of 33-day crops ; 3 - gas-exchange rate of 13-day crops.

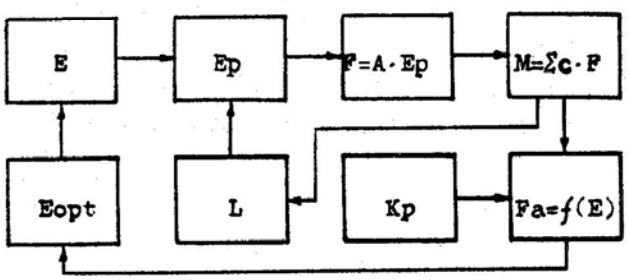

Fig. 2 - The computation scheme for accumulation of biomass in a crop at optimal radiation regime.

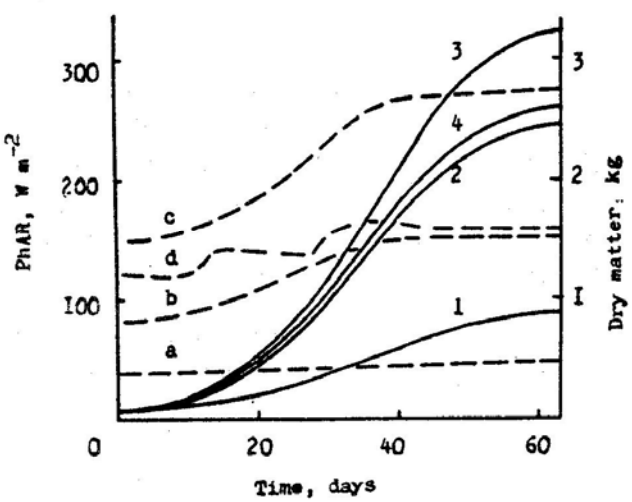

Fig. 3 - The dynamics of accumulation of dry biomass in wheat crops at optimal radiation regime. Curves : 1 - efficiency of a crop CF/E (the ratio of daily biomass increment to the amount of PhAR) ; 2 - daily biomass increment CF ; 3 - a product of CF/E, CF (2) ; 4 - experimental curve ; a, b, c, d - are corresponding irradiances.

IX - THE EFFECT OF THE ACTION OF THE SPECTRUM AND OF LIGHT INTENSITY IN TERMS OF THE LENGTH OF THE PHOTOPERIOD

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Between 1954 and 1974, morphophysiological research was done at the laboratory of Plant Development on the influence of the spectrum and light intensity in terms of the length of the photoperiod on organogenesis and the rhythm of the development of various species, varieties, ecogeographic groups and types of plants cultivated. In the tests more than 1000 samples were observed, originating from the collection of the N. I. Vavilov Plant Culture Institute (Kuperman, 1961, 1973 ; Rjanova and Akhoundova, 1961, 1963, 1970 ; Choulgin, 1962, 1965, 1973 and others).

The analysis of light action on plant development was studied by characterization of all organogenesis steps, which permits a comparison of information obtained from various varieties and plant in experiments, according to unification of estimated units for ontogenesis (3).

The experiments were done in two types of specially equipped chambers (photoperiodic chambers). In the photoperiodic chambers of phytotron of the first type, plants are cultivated exclusively in artificial lighting. In each of the 8 chambers fluorescent lamps were set out along four walls and also suspended on a mobile frame in the ceiling so that top and lateral lighting is ensured. If necessary, in an upper frame, to the fluorescent lamps can be added at the same time, incandescent lamps and various gaz discharge lamps having different irradiation spectra. Depending on the experimental problems daylight lamps (DC), blue (L-29, L-30), red (L-37, L-27, L-26) or green (L-35) were used. The length of the photoperiods were automatically regulated. In the experiments, this length of daily lighting period varied within the limits of 6 and 24 hours for daily photoperiods with possible intervals of 0, 5 hours of light and dark. The lighting intensity was modified by lighting a number of variable lamps or else by adjusting the height of the frame above the plants (between 30 and 200 cm). In each photoperiodic chamber on a 1,8 m^2 surface, 24-32 pots were set out. The temperature was regulated by ventilation.

The second type of photoperiodic chambers in a phytotron make it possible to cultivate plants in natural open platform and vegetation house during 8-12 hours (from 8 and 16 hours, or from 8 and 20 hours) in conditions of combinations of natural light with complementary artificial lighting in the photoperiodical chambers (from 16 hours until 8 hours in the morning on the next day) with different qualities and intensities. Plants in vegetation vessels placed on the trolleys are rolled into the chambers ; where in conformity to particular experimental schemes lamps of different light spectra are switched on at various intensities for 4 hours (from 16 till 20 hours) for short day plants (12 hours), or for 8-16 hours for long day plants (16 or 24 hours). In this chamber it is possible to cultivate plants all the time under artificial light.

Therefore, the advantage of photoperiodic chambers of the second type lies in the fact that the plants, during 8 hours per day, receive normal conditions for photosynthesis and other metabolic processes. On this basis the additional artificial lighting made it possible to study more completely the result of the influence of the spectrum and of the different light intensities on the plant.

In photoperiodic chambers of both types, experiments are organized for studying effects of photoperiods of different structure (changing blue light for red, interrupting day time by dark or other changes). 68 series of tests were done, which were subdivided into the following variant groups:

1) plants were cultivated for 80-100 days in artificial conditions in 8 photoperiodic chambers under fluorescent lamps of white, red, blue and green. The lengths of the photoperiods of each spectrum were : 4, 6, 8, 10, 12, 14, 16, 20, 22, 24 hours.

2) from 8 a. m. to 4 p. m. the plants were cultivated on a platform and vegetation house in other words, they were in natural lighting conditions for 8 hours. Afterwards, the plants were placed on trolleys in the photoperiodic chambers, where for 4, 8 or 16 hours, they were lit additionally by red, blue or daylight lamps.

3) plants were cultivated for 2, 4, 6, 8 hours in artificial lighting of a different spectral quality and after were moved into the platform in natural lighting.

4) plants received additional artificial light of various spectra in two portions of 2, 3, 4 hours before and after 8 hours of natural lighting (conforming to photoperiod lengths of 12, 14, 16 hours).

5) plants, after 8 hours of natural lighting were moved into photoperiodic chambers and received lighting successively during 24 hours : in one subject, 2 or 4 hours of red light and afterwards blue light and in other subjects, conversely, red following the blue. In this case, the influence of a "final lighting" of the spectrum was studied on organogenesis.

6) Short and long photoperiods were interrupted by 2, 4, 6 hours of darkness and then additional artificial lighting of a different spectrum was applied.

7) Plants were passed through different photoperiods and spectra during different stages of organogenesis : during stages I-II, **III** -IV and finally X-XI.

8) Plants were cultivated under different light intensities, in artificial and also natural conditions, where plants were covered by layers of gauze. It should be noted that in artificial conditions (photoperiodic chambers) due to unreliable working of the lamps, certain variations in lighting intensity were sometimes observed. These variations between variants are not important, as can be seen in the published results of these experiments.

In the tests with two different ecotypes of millet : late variety, Prokhladnenskoe, originating in the south, and a northern precocious, Omsk 9, different kinds of spectrum (day light, blue, red and green) were studied at different photoperiods from 6 hours until 24 hours with intervals of 2 hours (6, 8, 10, 12, etc.).

It was observed that the action of the spectrum (as concerns the speed of development and of organogenesis) is revealed in photoperiods very slightly different from the optimum. For the short day ecotype, it occurs for photoperiods of 14 to 16 hours, and for the long day ecotype, between 10 to 14 hours. The influence of the spectrum is not observed in optimal photoperiods (12 hours photoperiod) as in photoperiods of extreme limits. These latter (from 18 till 24 hours) completely inhibit plant development.

In this case (Table 1) one can see differences between Omsk ecotype (boreal) and Prokhladnenskoie (south) which are adapted to different photoperiods.

Identical results were obtained with long day plants : wheat, barley, radish (Table 2), dill (Table 3) and others.

Therefore, the reaction of plants to a determined spectrum reflects their origin, as well as their intraspecific differentiation in separate ecotypes.

Given the different action of the spectral quality of the light in terms of the length of the photoperiods, we have introduced the following complement to classification of plants according to their reactions to photoperiod durations and light quality :

. long day plants flowering preferably with red
. long day plants flowering with blue
. short day plants flowering preferably with blue
Short day plants flowering with red

Table 1. - Duration of organogenesis stages for two morphophysiological types of millet depending on photoperiod length and spectrum of light in the chambers.

photo-period	light	Prokhladnenskoe (south)					Omskoe (Boreal)				
		Organogenesis stages									
		I-II	III-IV	V-VI	VII-VIII	IX-XII	I-II	III-IV	V-VI	VII-VIII	IX-XII
6	blue	30	dying		-	-	30	dying		-	-
	red	29	-		-	-	30	-		-	-
8	blue	14	2	9	8	23	13	6	4	12	18
	red	15	2	11	8	23	14	7	5	11	19
12	blue	13	8	12	7	25	13	3	8	12	16
	red	16	5	10	11	26	14	7	7	6	16
16	blue	19	14	14	8	26	14	4	8	10	18
	red	32	40	-	-	-	17	6	6	9	19
20	blue	61	remain at II stage				20	5	-	-	-
	red	-					35	remain at II stage			
24	blue	88	remain at II stage				28	35	4	-	-
	red	88					27	remain at II stage			

Table 2. - Influence of light spectrum with various photoperiod lengths on passage through organogenesis stages by various morphophysiological type of radish (experiments in photoperiodical chambers with complementary fluorescent lights).

Morpho-physio-logical type	Variety	Light conditions (I)											
		8e + 16c				8e + 4c				8e + 4k			
		days											
		10	15	21	60	10	15	21	60	10	15	21	60
I	Faizabad Kalmi whiete	IV	VII	IX	XII	III	V	VI	XI	II	IV	V	IX
2	Cavalier	III	IV	VI	VIII	II	III	IV	VI	II	II	III	V
3	Novinka	II	III	IV	VII	II	III	IV	IV	II	III	III	IV
4	Red giant	II	III	IV	VI	II	II	III	IV	II	II	II	IV
5	Tchan-chin-Loho	II	II	II	V	II	II	II	IV	II	II	II	IV
6	Red Kishinev	II	II	IV	V	II	II	II	IV	II	II	II	IV

(I) : e - natural light ; c - blue light ; k - red light

Table 3. - Influence of photoperiod length and complementary light on passage through organogenesis stages by dill.

N° of VIR catalogue	Morpho-physiological type	Origin of plants	Light conditions (1), hours: 8e+16c (LC)			8e+16k (LK)			8e+4k (KK)		
			Days								
			20	45	65	20	45	65	20	45	65
295	First	Finland	II	VII	XI	II	VII	XI	I	II	II
233	Second	Armenia	II	VII	XI	II	VIII	XI	II	II	II
94/71	Third	Afghanistan	II	VII	X	II	VII	X	II	II	II
79/137	Fourth	Turkey	II	V	X	I	V	VIII	I	II	II
314	Fifth	Bulgaria	II	IV	VI	I	II	V	I	II	II
289	Sixth	Kazakhstan	II	IV	IV	II	IV	IV	I	II	II

(1) : e - natural light ; c - complementary blue fluorescent lamps L30 ; k - complementary red fluorescent lamps L27 ; LC - long day, blue light ; LK - long day, red light. ; KK - short day, red light.

The factor of analysis for annual species of leguminous plants that have stenophotoperiodic reactions is a 24 hour lighting period (8 hours natural + 16 hours red light).

Experimentally it was established that a "final lighting effect" of the spectrum is caused even with an interruption of the photoperiod by darkness, during 2-4 hours.

Irradiation of short day plants before their transplantation to the platforms in natural daylight is le ss effective than their irradiation after natural daylight. For long day plants, for example beans, it is the contrary : red light is more efficient during the earlier hours of the day, before the transportation of plants into natural daylight. Beans were developed in various ways in terms alternating natural lighting with high intensity and complementary artificial lighting of weak intensity, even though the length of photoperiod was the same, 16 hours. When red light of weak intensity precedes natural light (variant : 8 hours red light + natural light), plants reached stage IV in 17 days, and when natural light preceded red light of weak intensity the beginning of differenciation of growth vegetation conus was delayed until 48 days.

Much stronger was the influence of alternating natural daylight with blue light of weak intensity. Thus in the variant 8 hours blue light + 8 hours natural daylight, stage IV of organogenesis begins at day 31 and for the inverse variant ; 8 hours natural, daylight + 8 hours blue light, growth of vegetation conus remained at stage II of organogenesis until the end of the observation.

Therefore beans according to their photoperiodic reactions are very near to long day plants - their development is quicker in 16 hours photoperiods complemented with red light particulary when this complementary weak red light precedes natural daylight.

The "final lighting effect", the action of various light spectra as well as the experiments with light interruption, leads us to conclude that for the rhythms of development and organogenesis of plants, there is an influence not only of the lengths of the photoperiods in a 24 hour cycle, but also Of its quality (Table 4), (3, 10).

Table 4. - Organogenesis stages of white mustard (II-X) in various light conditions with different compositions of natural light (e) and complementary red (k) and blue (c) light.

Object	Photoperiods (hours) and order of light interchanges	Number of days from shoots 14	33	50
1	16 (8e + 4c + 4c)	III	IV	IX-X
2	16 (8e + 4k + 4c)	III	V-VI	IX-X
3	16 (8e + 4k + 4k)	II	IV	V -VI
4	16 (8e + 4c + 4k)	II	IV	V -VI
5	12 (8e + 4c)	II	III	IV-V
6	12 (Be + 2k + 2c)	II	III	VI
7	12 (8e + 4k)	II	II	IV
8	12 (8e + 2c + 2k)	II	II	IV

Table 5. - Effect of light on plants at various organogenesis stages

Light conditions	Wheat					Mustard					Millet					Tomato				
	Organogenesis stages																			
	II	III-IV	V	VI-VII	X-XII	II	III-IV	V	VI-VII	X-XII	II	III-IV	V	VI-VII	X-XII	II	III-IV	V	VI-VII	X-XII
24 hours red light	+	+++	++	+	o	-	+	+	-	o	--	---	-	-	o	-	++	+	+	+
24 hours blue light	o	+	+	o	o	++	+++	++	+	+	-	--	+	+	+	-	--	-	+	o
12 hours red light	--	---	-	o	o	--	--	--	--	o	+	--	+	+	+	+	+++	+	+	+
12 hours blue light	--	---	-	-	o	+	+	+	+	o	+	+++	++	++	+	+	+	+	o	o

Comments : +++ denotes the greatest effect of light expressed in accelerated rates of development (shorter organogenesis stages), rises of growth processes . ++ and + denote accordingly smaller effects. ---, --, - : effects of inhibition of rates of development or growth intensity. o denotes absence of effects or difficulty in detecting effects.

Table 6. - Differenciation of generative organs of lentil plants (Penzenskaia 14 variety) in natural light conditions (8 hours) complemented by fluo-rescent lights (16 and 4 hours) of different intensity and spectral composition,

light condition	Red		Blue	
	3000 ergsjcm2/sec	6000 ergs/cm²/sec	5000 ergs/cm²/sec	15000 ergs/cm²/sec
24 hours (8 h natural light + 16 h fluorescent light)		VI-VII	**VII**	**XI**
12 hours (8 h natural light + 4 h fluorescent light)	V			VI
	V	V	V	

Experiments on the action of light at various stages of organogenesis showed that plants are most sensitive to lighting states during stages III-V of organogenesis/short day plants like long day plants of many species varieties and families are absolutely indifferent to the lighting regime during stages X-XI of ontogenesis (photoperiod and spectral composition of light) (2, 8, 9), (table 5).

However, a large group, called neutral plants, with large seeds or biennials with reserve organs react more to the spectral composition of light in stages X-XII of organogenesis which is observed during the second year, or during the first stages of the development of the first generation (4, 6).

Experimentally, the great importance of light intensity has been demonstrated. Numerous leguminous plant varieties (e. g. Ornithopus sativus, Vicia sp. , Cicer arietinum, lentils, small seed peas) do not reach stages IX of organogenesis if the light intensity is weak, even in conditions of an optimal photoperiod of 24 hours (4, 5), (table 6).

The experience of 20 years of work makes it possible for us to recommend the use of phytotrons for vegetation so as to evaluate selection material, research on the photoperiodic reactions of plant resources, as well as for establishing culture methods for greenhouse plants in the autumn, winter and early spring.

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X - COMPETITION FOR LIGHT : A PHYSIOLOGICAL MECHANISM I

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Abstract.

In the garden pea (Pisum sativum L. cv Alaska) the pigments that control leaf and stem development vary, depending upon the competitive conditions under which the plants grow. In plants grown under a thick leaf litter, the pigment phytochrome inhibits stem elongation and promotes leaf expansion. The pigment protochlorophyll apparently controls stem and leaf development in plants grown under intense competition. In plants grown in full sunlight, stem and leaf growth are controlled by two pigments, one absorbing blue light, the other yellow. These three pigment systems provide a possible physiological mechanism by which plants compete for light.

Introduction.

Stem elongation and leaf expansion have long been recognized as complimentary responses in light-controlled shoot growth (Parker et al., 1949). Studies of plants grown in artificially-controlled light conditions indicate that several different photosystems coordinate shoot growth depending on light conditions under which the plants were grown (Elliott and Miller, 1974 ; Elliott, 1975) :

1. The pigment phytochrome controls stem and leaf growth in dark-grown plants (Parker et al. , 1949). 2. Elliott and Miller (1974) grew plants under dim red light. The action spectra they obtained for stem and leaf growth were very similar to the absorption spectrum of protochlorophyll, and this pigment may indeed be the photoreceptor controlling shoot growth in these plants. 3. In light-grown plants, shoot coordination is controlled by two high energy reactions absorbing in the blue and yellow regions of the spectrum (Elliott, 1975).

The purpose of this paper is to attempt to elucidate the importance of the photosystems discovered under laboratory conditions to the life of the plant. Leaf and stem coordination are important in overtopping, the competitive process in which the plant elongates its stem above competitors, then expands its leaves. The experimental conditions described above seem to simulate the natural habitat of the seedlings. The young plant begins its growth in darkness beneath a covering of leaf litter ; next it exits in dim light beneath the green leaves of neighboring competitors. Once the plant overtops its competitors, it is growing in full sunlight.

In this paper we describe a series of experiments in which plants were grown under the three kinds of competitive conditions described above. We wished to determine whether the responses of these plants indicated activity of the same photoreceptors found in plants grown under artificial conditions.

Materials and methods.

Pea seedlings (Pisum sativum L. cv Alaska) were grown for one week under three competitive conditions (see Fig.1). One group was grown in light proof containers covered with about 0. 5 m of dead oak leaf litter (dark plants). Another group was grown in light proof containers covered with green leaf filters made of a single layer of fresh geranium leaves between two glass plates (competition plants). The last group was grown in full sunlight (light plants). The experiments were repeated in a greenhouse and a Percival PGC-7 growth chamber.

After one week, we conducted experiments to determine the photosystems controlling shoot growth in each group of plants. In all experiments, growth of leaf and stem was measured as change in length of a 2 mm segment marked at the beginning of a 24 hr experimental period.

1. Dark plants were subjected to four different treatments to test for phytochrome activity : a) complete darkness (i. E., no treatment), b) 30 minutes of red light (660 nm), c) 30 minutes of far-red light (730 nm), and d) 30 minutes of red followed by 30 minutes of far-red light. After each treatment, leaf and stem growth were measured after an additional 24 hr period of darkness.

2. Competition plants were also tested for phytochrome activity as described for dark plants. Since these experiments yielded negative results, further experiments were done to determine whether single colors of light affected stem and leaf growth in these plants. Growth of leaf and stem was measured after 24 hr in light of one of the following colors : blue (440 nm), green (520 nm), yellow (580 nm), orange (620 nm), red (660 nm). Elliott and Miller (1974) list the combinations of cellulose acetate filters used to obtain light of each wavelength. All seedlings received a total dose of 5 x 10^{19} photons cm^{-2} over the 24 hr experimental period.

3. Light plants were tested for sensitivity to various colors of light as described for competition plants. Since no single wavelength of light affected shoot growth significantly, various combinations of wavelengths were tested simultaneously. The following combinations were obtained by making mosaics of cellulose acetate filters : blue and yellow (440 and 580 nm), blue and red (440 and 660 • nm), green and red (520 and 660 nm). Again, adjustments were made to assure that all seedlings received the same photon dose over the experimental period.

Results and discussion.

Distinct photosystems acted to control shoot growth in plants grown in each of the three competitive conditions (Fig. 1).

Dark plants. Phytochrome was clearly the pigment controlling stem and leaf growth in plants grown under a thick leaf litter. Stem growth was inhibited and leaf growth was promoted by red light (Fig. 2). In each case the effect of red light was reversed by far-red light. Far-red reversibility of the effect of red light is the familiar indication of phytochrome involvement in shoot growth (Parker et al. , 1949).

Competition plants. No phytochrome activity was found in plants grown under a green leaf filter (Fig. 3, top). Tests on the effectiveness of individual wavelengths of light showed significant inhibition of stem growth and promotion of leaf expansion in blue (440 run) and orange (620 nm). Blue light was somewhat more effective than orange.

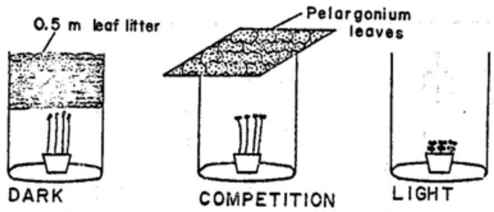

Figure 1. Three competitive conditions under which pea seedlings were grown: DARK plants, COMPETITION plants, LIGHT plants.

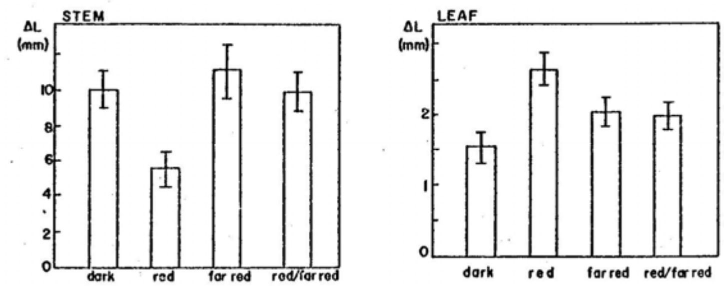

Figure 2. DARK plants. Influence of darkness, red, far-red, and red followed by far-red on stem (left graph) and leaf right graph) growth. Each light treatment was 30 minutes in duration. Growth was then measured after an additional 24 hr in darkness.

These results are similar to those reported for plants raised under dim red light (Elliott and Miller, 1974 ; Elliott, 1975). Plants growing under a green leaf canopy are exposed primarily to far-red light (Stoutjesdijk, 1972). The effect on growth of far-red light given over an extended period is similar to that of red light (Mohr, 1974).

Wavelengths of 440 nm and 620 nm most effectively controlled shoot growth in competition plants (Fig. 3). These action peaks correspond generally to the absorption peaks of protochlorophyll. A similar correspondence between a more detailed action spectrum for shoot growth of plants grown in dim red light and the absorption spectrum of protochlorophyll has been reported (Elliott, 1975). In both cases protochlorophyll is probably the photoreceptor controlling shoot growth.

Light plants. No single wavelength of light is effective in controlling shoot growth in plants grown in full light (Fig. 4, top). When combinations of wavelengths were tested, we found blue and yellow light in combination were most effective in coordinating shoot growth. Apparently two pigments, one absor - bing in the blue and the other in the yellow regions of the spectrum, control shoot growth in these plants.

Conclusion.

Thus we have shown that photosystems discovered in plants grown under artificial light conditions do indeed function when the plants are grown under more natural conditions. The photosystems controlling shoot growth change as the plant moves successively from darkness below a leaf litter to dim far-red light below the green leaves of competitors to full sunlight.

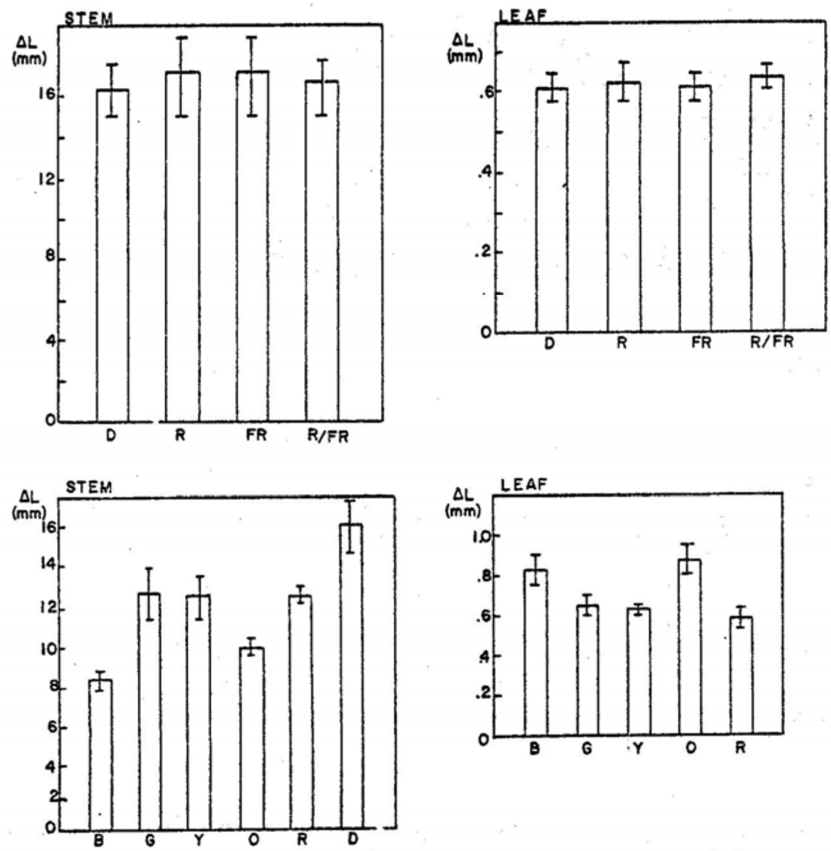

Figure 3. COMPETITION plants. Top graph: Influence of darkness, red, far-red, and red followed by far-red on stem (left graph) and leaf (right graph) growth. Each light treatment was 30 minutes in duration. Growth was then measured after an additional 24 hr in darkness. Bottom graph: Influence of blue (B), green (G), yellow (Y), orange (O) and red (R) light given continuously over a 24 hr period on stem (left graph) and leaf (right graph) growth.

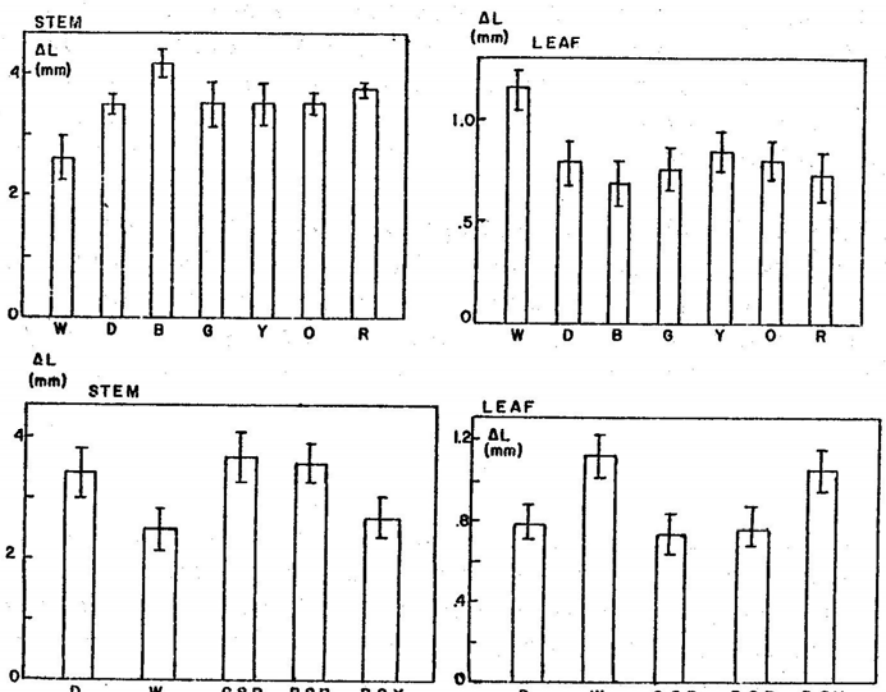

Figure 4. LIGHT plants. Top graph: Influence of blue (B), green (G), yellow (Y), orange (O) and red (R) light given continuously over a 24 hr period on stem (left graph) and leaf (right graph) growth. Bottom graph: Effects of several combinations of colored light on stem (left graph) and leaf (right graph) growth. Light treatments were given continuously over a 24 hr period.

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XI - PHOTOMETERS FOR PHYTOTRONES

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Photometers whose spectral sensitivity approaches the rectangular function Phar (380 to 710 nm) and the relative photosynthesis radiation efficiency functions for a leaf and a plant family have been developped. The function for a leaf has been obtained according to averaged experimental data of K. J. Mc Cree (1) taking into consideration P. Gaastra's results (2) and our own experimental results (3). The relative photosynthesis efficiency function for a plant family has been defined on the basis of an analogous function for a leaf taking into account the fact that a plant family has a higher absorption of a radiation in the green and far red spectrum ranges, in comparison with that of a leaf (4).

The photometers have the same principal optical and electrical scheme but different spectral sensitivity approaching Phar and photosynthesis radiation efficiency for a leaf and a plant family (Fig. 1). Each instrument has two changeable feeders for measuring the irradiance on a plane and the mean spherical irradiance. Silicium photodiodes serve as the receivers of a radiation. The spectral sensitivity correction was made with colour filters using the additive-subtractive method. A light arrow microampermeter of a small inner electrical resistance is used for photocurrent measurements.

In usual phytotrone conditions the total instrument error caused by an inaccuracy of the correction of the spectral and angular sensitivity does not exceed 10 %. The instruments have three scales differing in sensitivity as 1 : 10 : 100. They are calibrated for watts or effective watts at a meter square. The maximum sensitivity of the instrument together with the feeder for measuring the irradiance on a plane is— 1 1N/111^2/sc. div. and with the feeder for measuring the mean spherical irradiance is — 5 Wim^{2}isc. div. The feeder weight is about 100 g.

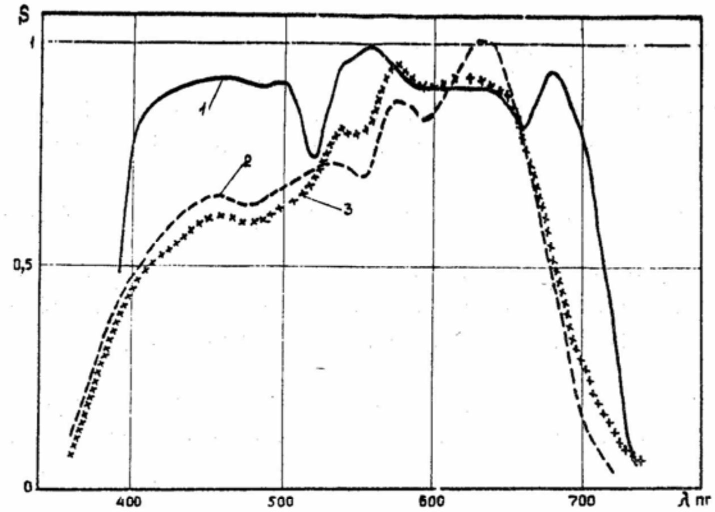

Fig. 1a - Photometers spectral sensitivity. 1 - PhAR ; 2 - photosynthesis for a leaf ; 3 - photosynthesis for a plant family.

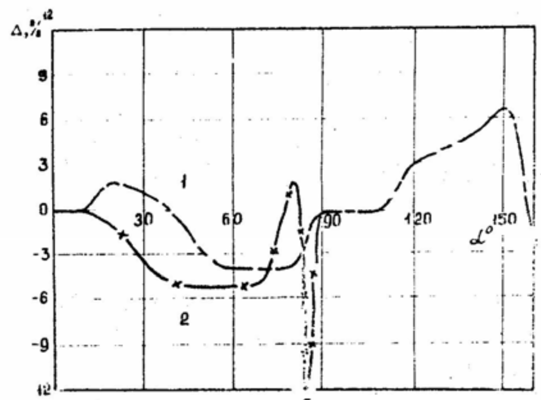

Fig. 1b - Error of geometrical sensitivity. **1 -** spherical photometer ; 2 - plane photometer.

The economic effect of growing plants in phytotrons is not only determined by a photosynthesis efficiency but depends also on the radiation spectral composition, periodicity and intensity, the light beam geometry, mineral and gas nutrition, humidity, temperature and magnetic field. A great variety of influencing factors and the absence of an agreement on the standard method of the plant irradiation in phytotron conditions hamper obtaining absolute values when growing plants and lead to the impossibility of comparing the results of different laboratories on the evaluation of the efficiency of various sources of radiation.

As there are not enough knowledge on some spectral radiation efficiency functions influencing growth, development, dry weight, carbohydrate, albumen etc. accumulation, as well as quantitative data on the relative importance of these factors, and taking into consideration the additive failure in different spectral radiation effect on the plants being raised, it is impossible to evaluate by means of a calculation the full radiation efficiency for the plants using a many-dimensional vector space of the spectral radiation efficiencies. To approach this problem it is necessary to have a radiation evaluating system which would be founded not only on the base function of the spectral radiation efficiency but also on a standard method of irradiation.

A correct choice of a base function should ensure the additivity of the multy-spectrum radiation effect and an easiness of its imitation by using a physical receiver. It would permit to measure correctly an irradiation in phytotrons. A standard method of an irradiation is based on a fixed source of radiation and a certain geometry of light beams. The spectrum of a source radiation should in main correspond to the range of a physiologically active radiation. The source should be stable and effective when used for a light culture.

Of a vast number of the proposed functions of the spectral radiation efficiency according to the radiation effect on the plants PhAR is the most suitable one for being used as a base function. As a source of radiation xenon and mercury lamps widely used now in phytotrons can be applied. A diffuse type of illumination is the most convenient for a standardization.

Standard methods of the plant irradiation will permit to compare efficiencies of different spectrum radiations in a light culture, that is necessary for developing an optimal source and for controlling the spectrum and the intensity of a radiation in the process of a plant culturing. The comparative results of such experiments made in different laboratories can be obtained only when raising plants in the conditions when all the influencing factors (including a constant irradiance in PhAR region) but the one being studied are fixed, and when two instead of one irradiating installations are used, i.e. the tested and the standard one. A correlation of the irradiances when using the test and the standard installations giving the same biological effect will permit to judge the efficiency of a tested source radiation and to compare different sources and irradiating installations according to their efficiency.

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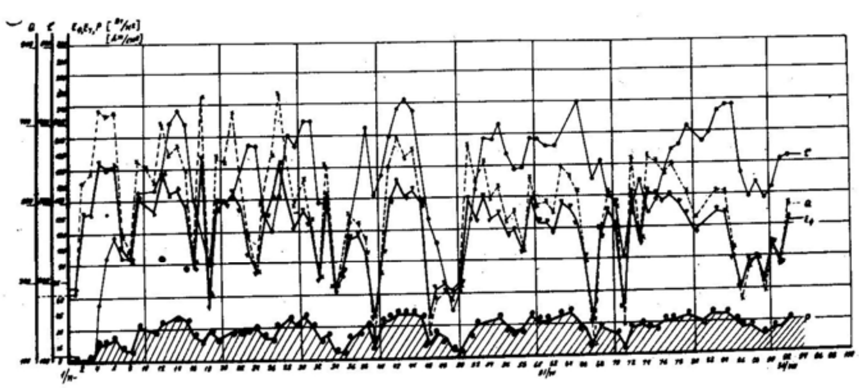

Figure Legend: Dynamic of cumulated variations of the diurnal values of: Temperature (t°) ,global lighting,phytoenergetics (E) and P during a 1967 growth period for tomato culture.

XII - QUANTITATIVE EVALUATION OF ENERGETIC FACTORS WHICH LIMIT PLANT PRODUCTIVITY

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When plants are provided with their mineral nutrition and indispensible water, their productivity is limited, apart from their hereditary properties, by energy admission from optic radiation (light) and by heat from the ambient surrounding environment, characterized by Energetic-Temperature Factors (EF). An artificial admission of these factors in the growth chambers, greenhouses and Phytotrons, as well as their regulations in natural conditions in the aim to maintain growth and plant development at an optimal level requires, in most cases, great material and energy expenditures compared to other non-energetic factors (mineral nutrition, irrigation, etc.). The optic irradiation (lighting) state and temperature state play the most important role, as we all know, on plant growth and development. The temperature of the surrounding environment represents a means of maintaining thermic energy, which has been shown experimentally (1) can be replaced by heating plants by radiation. The proximity of these EF, as to their physical nature, indicates the need for an appreciation of the complexity of their action on the plant.

Photosynthesis being the main bioenergetic process in agricultural productivity, in the quantitative estimation of the EF which limit plant productivity, it is necessary to take into account the expressed laws of photosynthetic activity (PSA) using corresponding models as a basis, and described by analytic equations. This will eventually help in creating a biomathematic model, acceptable for practical aims, for estimated productivity of natural cenoses and for programming crop formation.

To estimate the effectiveness of optic, photosynthetic and thermic radiation on the plant, preference must be given to effective values (indicated) which take into account the selectivity and sensitivity of the receptor that receives the radiation (2, 3). Effective energetic lighting values, which take into consideration basic energetic actions of optic radiation on the plant, will be expressed in the following way :

. for phytolighting : $$E_{\varphi} = g_m(\lambda) \int_{\lambda_1}^{\lambda_2} K_{\varphi}(\lambda)\,\psi(\lambda)\,d_{\lambda},\ \mathrm{W/m^2} \qquad (1)$$

. for thermic lighting : $$E_T = \int_{\lambda_1}^{\lambda_3} K_T(\lambda)\,\psi(\lambda)\,d_{\lambda},\ \mathrm{W/m^2} \qquad (2)$$

were : $g_m(\lambda)$ = maximum photosynthetic spectral effectiveness for optic radiation ; $K_T(\lambda)$ = relative spectral effectiveness of the thermal action of optic radiation on an "average" leaf ; $K_{\varphi}(\lambda)$ = relative spectral effectiveness of photosynthesis for an "average" leaf ; $\psi(\lambda)$ = spectral intensity of optic radiation $\mathrm{W/m^2}$. nm ; $\lambda_1\ \lambda_2\ \lambda_3$ = integration limits.

However, the quantity of the effective photosynthetic energy (phytoenergy) of radiation used by plants depends, for optimal values of non energetic factors, on the existing relation between three indexes of the energetic state of the environment which immediately surround the plant - phytolighting (PL), thermic lighting (E_T) and temperature (Ta).

In the case where all photosynthetic energy participates in the process of photosynthesis, a determination of phytoenergy during a certain length of time, useful for photosynthesis, can be determined by a normal summation (as is done in determining, for example, radiation doses) conforming to the equation :

$$\Phi = \int_s \int_o^t E_\varphi (\gamma, s)\, d\gamma ds \qquad J.(3)$$

with : t = time in seconds ; s = surface of the zone of irradiation in m^2.

In reality, as can be seen in our tests, in the case of a non optimal relation of the various values, EF-E_T, PL and Ta, not all the phytoenergy can be used in principle for photosynthesis and a certain part, due to lack of coordination between the factors indicated, can be transformed into thermic and other kinds of energies.

An analysis of solutions for the energetic balance equation for green plants (4, 5), theoretical research on plant photoenergy (6), experimental values for a study of relations between the speed of photosynthesis and air temperature for different values of phyto and thermic irradiations (5, 7, 8) show that the PSA of plants for all exterior conditions in a favorable environment, depends on the EF relation in time. For all plants there is an optimal combination of EF conditions of the environment for which the speed of productive photosynthesis has its maximal value. The influence of the air temperature (Ta) in this case is optimum for the given values E_φ (1) and E_T (2). On the basis of the approximation of experimental values, the analytic relation of optimal values for air temperature were able to be established in terms of E_φ and E_T

$$\text{Ta opt.} = T_o + nE\varphi - mE_T \qquad E\varphi \leqslant E\varphi_H$$
$$\text{Ta opt.} = T_m - m\left[(E\varphi - E\varphi_H) + E_T\right] \qquad E\varphi \geqslant E\varphi_H \qquad (4)$$

(4)

where : T_o = optimal value of air temperature surrounding the plant in obscurity ; T_m = optimal limiting value of air temperature corresponding to maximal phytoenergy ETH, n = coefficient specific to the type of plant, expressed in grad m^2/W ; m = coefficient specific to the type of plants expressed in grad. m^2P. V.

The total use by plants of photosynthetically effective energy depends on the difference there is at each instant between the ambient air temperature and the optimal temperature for photosynthesis for existing conditions of energetic lighting created by optic radiation, Consequently, the relation (3) can serve as a means of quantitative measurement for the complex estimation of optic radiation energy and of the temperature of the environment in agroclimatology and phytoactinometry, as long as, optima temperatures for photosynthesis in plants are taken into account.

The energy absorbed by the plants is partially transformed in the course of photosynthesis into energy of chemical links and the rest into heat, which from the viewpoint of photosynthesis, can be considered as direct losses. However, the heating of plants by radiations, as is seen by the relation (4), influences the effectiveness of the use of photosynthetically effective energy. The thermic action of radiation on the plant depends on the energetic lighting value of its spectrum. Thus, in the spectrum of solar radiation, thermic flux represents about 30-40 % of the global (according to the height of the sun on the horizon). 17 % - in the spectrum of DRL-1000 lamps and 28 % in the spectrum of fluorescent LDC-40 lamps.

The thermic flow, modifying the temperature of photosynthesizing organs, modify the optima values of temperature for photosynthesis and, consequently, it must absolutely be taken into account in the complex quantitative estimation of the energetic action of optic radiation on the plant and for determination of its productivity. A similar need appears above all in estimating the maxima possible effectiveness of various cenoses in various climatic zones.

To resolve numerous culture problems (economic appreciation of land, programming and forecasting harvests, forecasting zones for possible improvement and for use of terrains, etc.), it is also indispensible to quantitatively appreciate the complex of natural EF, which limit plant productivity and the for-. mation of their yields. There are several methods proposed to appreciate agro-meteorological factors : the sum of bioclimatic temperatures, bioclimatic (IBC) index, summation of solar radiations during growth period (9). Using as a basis the absorption spectrum of plants, as well as the spectral limits of the region of the photosynthetic active spectrum, since about 1956 the notion of PAR, photosynthetically active radiations, is used. Photosynthetically active lighting EpAR can be determined by the equation :

$$E_{PAR} = \int_{\lambda_1}^{\lambda_2} \psi(\lambda)\, d\lambda, \quad W/m^2 \quad (5)$$

were x_i = 320-400 nm and A2 = 700-800 rim are the generally admitted limits by the authors for the photosynthetically active part of the spectrum.

In most cases, there is a certain correlation between the PAR radiation energy and the summation of the temperatures of the environment, on the one hand, and plant productivity on the other. The more the PAR energy is raised, the larger will be the biological and economic yield. However, there is no direct relationship between these values and PAR.

Certain authors, basing themselves on this fact, point out the need for a combined estimation (complex) of the influence of light and temperature on the plant (10). Thus, for example, from Nanda's work (11), between the growth period (P_v), the average air temperature (T_{ma}), the average photoperiod (Ph_m) and a certain "photothermic quantum" (E) which represents the summations of diurnal temperatures during the growth period divided by the sum of the number of lighting hours during the same period ; following mathematic relation exist :

$$P_v = \sqrt{\frac{E}{Ph_m, T_{ma}}} \quad (6)$$

However, an estimation of optic radiations by measuring radiation values and values according to the PAR method are only purely physical methods of measurement. In this case the action of optic radiation on the plant is not taken into account. In global solar radiations at the level of the earth's surface, PAR represents on an average 50 % of the total optic radiation. However, about half of the PAR energy is in principle useful for photosynthesis. The existing methods of estimation of plant growth EF, requires still more work (12). McCREE, in the aim of specifying the PAR notion and of showing the real possibility for using this value in phytoactinometry, determined experimentally the spectrums of action for photosynthesis for more than 21 varieties of plants of different ecologic groups and species (13, 14). Using as a basis an analysis of the results, McCREE arrives at the conclusion that photosynthetic effectiveness of a radiation has a dependence clearly characterized by the wave length and thus, neither energetic lighting created by the visible part (PAR energetic lighting), nor even the emission of absorbed quantas, can be measurements of global photosynthetically effective radiation. These two values will surpass the effectiveness of the blue part compared to the red part of the spectrum. The value of the error thus allowed will depend on the spectral composition of the radiation (15). The results obtained by McCREE (13,14,15) confirm that an exact quantitative estimate of the photosynthetic effectiveness of the radiation can only be done by using as a basis the spectrum of action of photosynthesis. The practical coincidence of the spectrums of action of the photosynthesis on numerous groups and ecological species of plants confirm the accuracy of using the notion of an ideal spectrum for an "average" leaf of a plant (2,3).

The absence of an effective link between spectrums and ambient conditions (amount of CO2 and 02, temperature, lighting direction, etc.) as well as the adjunction to a monochromatic emission of "white" light, show possible additivity in photosynthetic actions of various spectral radiations and consequently a confirmation of the law of additivity in the use of photosynthetically effective values and units of measurement (2).

Thus, for a quantitative complex estimate of natural energetic factors limiting the crops one must above all take into account :

a) the spectral effectiveness of photosynthesis
b) the thermal action of radiation on the plant T-ET
c) the presence of photosynthetic temperature optimas clearly defined in plants.

Of all the meteorological factors which influence the harvest, the essential role belongs to solar radiation (16). Prof. A, A. Nichiporovich (17) writes : "... the more that harvest's increase, the more complex becomes the process of their increase... Following the measurement of optimization, factors such as levels of hydration and mineral nutrition are progressively eliminated from the basic minimum and other factors take their place... Modern research... must be based on an elaboration of a complex general theory... for the photosynthetic productivity of plants... ".

A quantitative estimate of optic radiation for its action on the plant is necessary as well for realizing new lighting equipment for greenhouses, growth chambers and phytotrons. Research on plant physiology, genetics, selection, seed production and agro-engineering, artificial climate, growth chambers and phytotrons will become more and more important. Lighting installations are of considerable importance because their specific power reaches several kilowatts per m_2 (18). The need for such high amounts of specific power is conditioned by the need to create energetic lighting indispensible for ensuring a high level of productive photosynthesis. Although other physiological plant processes, besides photosynthesis, also depend on irradiation, in general the luminous saturations of these processes are ensured by energetic lighting values much weaker than those necessary for photosynthesis. Using luminous sources in phytotrons and growth cabinets which produce a high yield, as regards photosynthesis, the specific power for equipment (air conditioner) which eliminates thermic surpluses in culture areas. This makes it possible greatly decrease the costs of construction and use of similar installations. Thus, the use of new luminous sources for type Lep-40, LOR-1000, LOR-2000 plants and others, make it possible to decrease installed power irradiation and expenditures for plants in greenhouses, growth cabinets and phytotrons by 40-80 % or else for analogous expenses to increase yields from 1,5-2 times more, compared to DRL or xenon lamps.

An analysis of theoretical research in plant photoenergetics as well as results in experimental research on the relation between the speed of photosynthesis in leguminous plants, the light and the temperature of the ambient environment done in the laboratory of the Agricultural Electrification Institute shows that in terms of criteria for a quantitative estimation of EF it is necessary to use a measure which takes into account the entire influence on the plant of photosynthetically effective energy, of the heating of photosynthesizing organs, of the radiation and of the difference between the temperature of the ambient environment and the optimal temperature for the evolution of photosynthesis, given in the case of energetic lighting (5). This is possible by means of a function which makes it possible to estimate concordance between the various energetic parameters for each precise moment :

$$\beta(E\varphi,\ E_T,\ Ta) = K_1\ (T_f - T_o) K_{2_e} - K_3\ (T_f - T_o) \qquad (7)$$

or $K_1\ (E\varphi)$, $K_2\ (E\varphi)$ are variable coefficients obtained by the method of the least logarithm, based on experimental study values for the relationship between the speed of photosynthesis and EF for plants.

The function of an optimal EF $\beta(E\varphi,\ E_T,\ T_a)$ relation makes it possible to introduce a new value, called bioenergetic potential P_1 which takes into account the bioenergetic characteristics of plants as well as the relationship between the speed of photosynthesis and various current exterior values of EF :

$$P_1 = \int_o^t \beta(E\varphi,\ E_T,\ T_a).\ E\varphi(\Upsilon)\, d\Upsilon,\ J/m^2 \qquad (8)$$

were (o-t) are time limits for which the value of the bioenergetic potential were determined.

The bioenergetic potential (BP) represents the summation for the quantity of energy of optic radiation that plants can potentially transform into chemical energy in connections with new substances, in the case of the existing thermic state and the irradiation state of other sufficiently favorable conditions.

The BP value can be calculated from the results observed in actynometric stations or else measured directly by means of a special apparatus.

Having for aim a preliminary control of the energetic critera introduced, calculations for the values of this parameter were performed according to the results observed in actynometric stations. With this aim in mind coefficients were set up for the passage of energetic values to effective values throughout the entire range of variations of the spectral composition :

$$M = \frac{\int_{\lambda_1}^{\lambda_2} K(\lambda)\psi(\lambda)\, d\lambda}{\int_{\lambda_1}^{\lambda_2} \psi(\lambda)\, d\lambda} \qquad (9)$$

(for the passage to phytolighting - $M\varphi$ and for thermic lighting - M_T)

Calculations were based on a comparison of the curves of variations of global lighting $Q_o(t)$ fonction to the moment of the day and phytolighting variations $E\varphi(t)$ and of thermic lighting $E_T\ (t)$ in identical physical conditions of the atmosphere. The value $Q_o\ (t)$ was obtained in two ways : 1) based on actynometric observations over several years, which makes it possible to take into account conrete atmospheric conditions of the zone studies ; 2) by analysis using optic characteristics of the atmosphere and astronomical formulas. In determining effective spectral light values of the sun, the spectrum was divided into i = 12 regions for which the average values of the following coefficients were determined :

$$< K\varphi(\Delta\lambda_i) > \frac{1}{\Delta\lambda_i} \int_{\lambda_i}^{\lambda_i + \Delta\lambda_i} K\varphi(\lambda)\, d\lambda \qquad (10)$$

$$< K_{T_i}\ (\Delta\lambda_i) > \frac{1}{\Delta\lambda_i} \int_{\lambda_i}^{\lambda_i + \Delta\lambda_i} K_T(\lambda)\, d\lambda \qquad (11)$$

The average values for the coefficient data (10), (11), were used to determine the effective values PL and ET in the middle of each hour :

$$E_{\varphi}(mn) = 0,95\,\Sigma_{i=1}^{12}\,\psi_i\,(mn)\,(\Delta\lambda_i) < K\varphi_i\,(\Delta\lambda_i) >,\ W/m^2 \quad (12)$$

$$E_T\,(mn) = \Sigma_{i=1}^{12}\,\psi_i\,(mn)\,(\Delta\lambda_i) < K_{T_i}\,(\Delta\lambda_i) >,\ W/m^2 \quad (13)$$

were ψ_i (mn) ($\Delta\lambda_i$) = spectral intensity of optic light corresponding to the spectral region ; m = number of days for the culture period $1 \leqslant m \leqslant 92$; n = number of hours during the day $1 \leqslant n \leqslant 17$.

According to the values (12) and (13) we obtained mn = 1564 values for each of the effective values for a growth period. Then, these calculated values were compared to the values Q_o (mn) for three growth periods. After these comparisons integration coefficients were obtained for transforming energetic values into effective values, according to the relations :

$$\left(\begin{array}{l} M\varphi\,(mn) = E\varphi\,(mn)/Q_o\,(mn) \\ M_T\,(mn) = E_T\,(mn)/Q_o\,(mn) \end{array} \right. \quad (14)$$

After mathematical elaboration of the values obtained from the coefficients for subsequent calculations the mean square values given in Table 1 were taken. This table gives integration values of the coefficients for the first half of the day, because for the 2nd period of the day they are the same, symetrically compared to the real value of a half day.

Table 1. - Average quadratic values of integration coefficients for the transformation of $M\varphi$ and M_T and for the first half of the day.

n	1	2	3	4	5	6	7	8	9
$M\varphi.10^3$	0,70 ±0,02	2,12 ±0,06	3,29 ±0,11	3,78 ±0,12	4,13 ±0,14	4,29 ±0,15	4,54 ±0,17	4,72 ±0,19	4,85 ±0,19
$M_T.10^3$	1,48 ±0,05	3,20 ±0,11	4,48 ±0,17	5,01 ±0,21	5,22 ±0,21	5,36 ±0,22	5,60 ±0,23	5,83 ±0,25	5,97 ±0,27

From the results of actynometric observations and using the values of the relation (7) and of Table 1, the values of global summation for P was calculated for every day of the growth period. Calculations were done for climatic conditions in latitudes = 58° l.N. and for three years : 1966-68. Figure 1 gives in graph form the results for the year 1967.

With theaim of establishing a correlation between existing and proposed bioenergetic criteria, for tomato crops, calculations were made for the sums of bioclimatic temperatures, PAR energy values, the summation of energetic lighting and BP for 1966-1968 culture periods. The results of the calculations for these values and the average values for tomato fruit crops for corresponding years are given in table 2 .

Based on the results of the calculations, the limits of variations are established for various energetic criteria and the correlation coefficients between various values of yield A and bioenergetic potential P (r_{PA} = 0,6) as well as between A and photosynthetically active radiation PAR (r_{PAR} ; A = 0,1). It was definitely concluded that the criteria so generalized and proposed for an energetic estimate of optic light in culture exceeds more than twice the precision of estimation with respect to other criteria in use at the present time.

Table 2. - Calculation results for the sums of effective T°, the sums of PAR and BP values for three years of culture,

years	ET°.10^{-4} > 5, 5°C	E PAR. 10^{4} (J/cm^2)	P. 10-4 (J/cm^2)	A (quintal/Ha)
1966	1,38	4, 57	0, 94	356
1967	1,41	4, 67	1, 02	381
1968	1,33	4,38	0,81	250

An energetic estimate of optic light for culture by means of P bioenergetic potential and the use of an automatic installation make it possible to estimate, in a more precise way, the effectiveness of possible varients for increasing various culture yields, to show the causes of a weak coefficient for effective energetic action for plants. The use of a measurement apparatus for an energetic estimate of the productivity of climatic resources will make it possible for actynometric stations and artificial climate stations to increase of effectiveness of scientific research and also will greatly aid in creating new means of artificial irradiation of plants, doing away with heating plants in greenhouses.

Comments.

1) DRL - 100 lamps - High pressure mercury lamp with corrected color.
2) Lcp - 40 lamps – Low pressure mercury fluorescent lamp for plant irradiation.
3) LOR - 1000 lamps - High pressure mercury lamps with lithium and indium iodide, for plant irradiation.
4) LOC - 40 lamps - Low pressure mercury fluorescent lamp, day light, for color transmission.

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XII THE INFLUENCE OF ENVIRONMENTAL CONDITIONS ON THE PARAMETERS OF CIRCADIAN RHYTHMS IN PLANTS

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The effects of temperature, light intensity and quality, absence of either N or P or Mg in nutrient solution on the parameters of circadian rhythm movements of bean leaves (Phaseolus vulgaris L.) were studied. The purpose of these experiments was to explain the relatively stability of period length of circadian rhythms at change in environmental conditions.

The plants were grown in water culture, first at light-dark cycle (LD) 12 : 12, then on continuous light (LL). The value of angle which the midrib of the primary leaf makes with its petiole was measured every hour during 2-3 days LL ; the repetition in variant was 10-20 leaves, Different temperatures gave 3-5 days before LL.

The free-running period (τ) of rhythm was longer at higher temperature (15°, 20° and 27° at light intensity 1500 and 6000 lx). A similar results were received in Gonyaulas polyedra (Hastings, Sweeney, 1957) and Oedogonium cardiacum (13uhnemann, 1955). However, in the majority of organisms' becomes shorter as the temperature is raised (Wilkins, 1965).

The length of day phase (a) of rhythm increased with the increasing of temperature from 15° to 20°, but decreased at 27° ; the length of night phase (p), on the contrary, increased at 27°.

Light intensity (1500 and 6000 lx) did not influence on τ the length of a was longer and the length of ρ was shorter at low intensity. The amplitude (A) of oscillation and mean value (MV) of this rhythm were little dependent on temperature and light intensity (Fig. 1).

The parameters of rhythm were different in plants growing under continuous light obtained from fluorescent lamps (FL) and incandescent lamps (IL). The emit of FL and IL has different proportion of red and far red radiant energy. Amplitude of oscillation, the length of τ and ρ were smaller while mean value and the length of alpha were greater in plants illuminated by IL than by FL. The increase of a did not completely compensate the decrease of ρ, therefore τ was less under IL (Fig. 2, I).

In plants growing during 2-2, 5 weeks in absence of either N or P or Mg the circadian rhythm (at LL) varied. The Mg-deficiency increased of mean value and length a, but decreased of length ρ; in this case there was no change inland amplitude of oscillation.

The N- deficiency reduced of mean value, length τ and alpha this effect was prevented by addition of N to the medium before LL. (Fig. 2, II).

In absence of ρ, the rhythm entirely damped in all plants after 1 day LL. The damping out of the rhythm was prevented by addition of p to the medium before LL ; in such rhythm the mean value and length a were smaller, but length ρ was greater than in the control ; length τ was the same as in the control (Fig. 2, II). The addition of ρ to the medium after 3, 5-4,0 days LL (when the rhythm had been lost) restored the rhythm (in 23 plants from 48). The position of the phases in such rhythm did not differ from that of the control, independently of the time of addition of P (84, 90 and 96 hour from the beginning of LL).

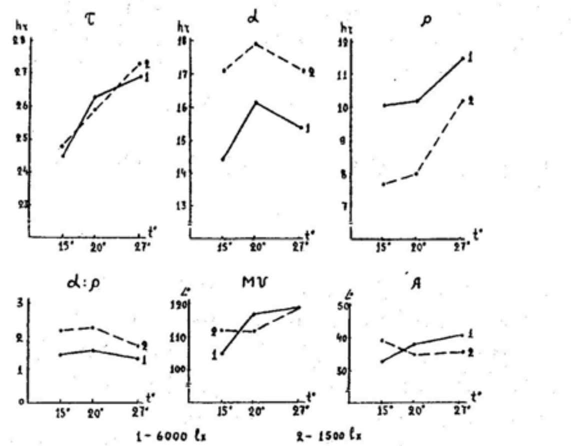

Fig.1. Effects of temperature and light intensity on the parametre of circadian rhythm.

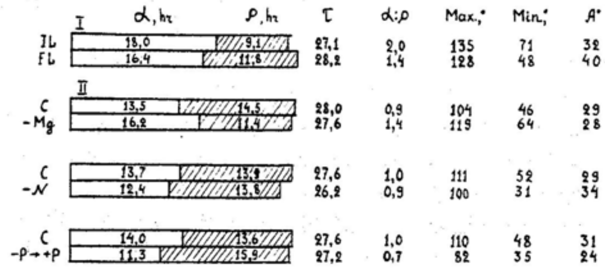

Fig.2. I- Effect of light quality on the parameters of circadian rhythm.
II- Effect of N-,P or Mg -deficiency on the parameters of circadian rhythm.

Its possible to suppose that oscillations of circadian clocks continue when a rhythm movement of leaves is damped ; only in absence of P the bond between mechanism of clocks and this rhythm breaks of.

The all results presented here show that changes in many environmental conditions change the length of alpha and ρ in opposite direction : if alpha lengthens, shortens, and vice versa, Therefore, relatively stability of τ is the result of opposite reaction of alpha and ρ on environmental conditions.

In other experiments the effect of constant temperature (15°, 20°, 27°) on the entrainment of the leaf movement rhythm by light-dark cycles (LD 9:9, 12:12, 14:14, 16:16) was studied (Fig. 3). Cycles 12:12 and 14:14 entrained the rhythm at all temperature while the cycles 9:9 and 16:16 entrained it only at temperature 15° and 20°, In these rhythms alpha/ ρ-ratio was the greater, the longer LD ; amplitude of oscillation decreased on LD 9:9 and 16:16. The phase angle difference (psi measured between a onset and light- on) has negative sign on LD 14:14 and 16:16 (advancing phase-shifts). The value of the phase angle difference was small on LD 12:12.

The positive phase angle difference increased with lengthening LD and the increa-se of temperature ; the negative phase angle difference (cycle 9:9) decreased with the increasing of temperature. The rhythm was not entrained by cycles 9:9 and 16:16 at 27°, it was free-running.

Therefore, ranges of entrainement of the leaf movement rhythm depends not only on parameters of LD-cycles, but also on the level of constant temperature.

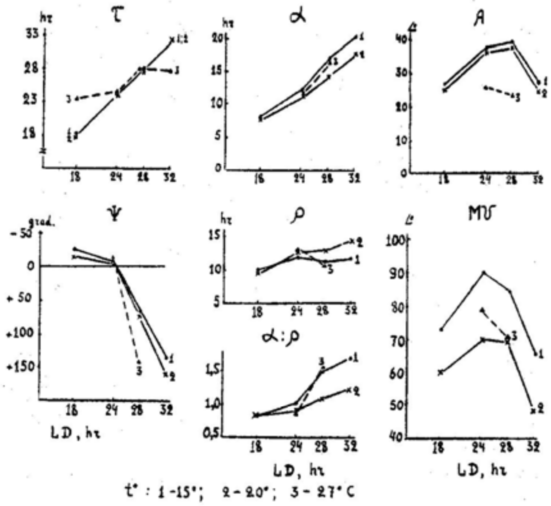

Fig.3. **The entrainment of the rhythm of movements of bean leaves by light-dark cycles at different temperatures.**

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XIV - ANALYSIS OF VARIANCE OF DISSIMILARITY COEFFICIENTS AS A TOOL FOR STUDY VEGETATION - ENVIRONMENT RELATIONSHIP

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LD, ha

There are a great number of different methods concerned with a problem of interrelationship of vegetation ande nvironment. They differ by their mathematical complexity and refinement and by different types of information used. The principal component analysis and related techniques are often considered as most useful methods for determining basic environmental factors that affect the vegetation (Yarranton, 1967a ; Gittins, 1969 ; van der Maarel, 1969 ; Fresco, 1969 ; Anderson, 1971). These methods determine the directions in multidimensional space with maximal variation in vegetation. They provide for an estimation of contribution of every axis to overall variation. But main directions of vegetation variation don't correspond to a single environmental factor (Loucks, 1962 ; Yarranton, 1967b) and their relations are not linear (Swan, 1970 ; Noy-Meir, Austin, 1970 ; Gauch, Whittaker, 1972) and therefore the ecological interpretation of principal components or factors is very difficult and partly misleading.

The proposed method is more direct although the analysed factors not always affect vegetation directly. It is based on a simple analysis of variance which is very familar to every biologist. Its advantages and drawbacks are well known. The mathematical basis is also very clear. Some peculiarities of the technique depend on the kind of the value under consideration. It is no quantitative character of objects as in conventional analysis of variance but a pair-function,

The difference between plots is estimated by any coefficient of dissimilarity. We use euclidean distance but other metrics can be applied with the same success too. In the case of qualitative factor such as types of soil, topographic position and so on, we subdivide the plots into groups in accordance with classes of factor.

So we can obtain the estimation of within group variance as a mean square of distances between plots of the group divided by half (Vasilevich, 1969). When the number of member of the group is sufficiently great, we can calculate the mean square of distances of plots from the group centroid. The centroid is the point in multidimensional space whose coordinates are equal to arithmetic means of cor-: responding coordinates of the group members. Both techniques give the same result. The pooled estimation of within-group variance is obtained by summation

of squares of deviation throughout all groups and by dividing them into corresponding degrees of freedom.

The intergroup variance can be estimated in the following way. The squared distance between every pair of centroids is calculated and their sum is divided by the number of pairs. We obtain the mean squared distance between centroids. The centroid distance can be obtained also from the matrix of inter-plot distances by means of the equation

$$(M_K - M_1)^2 = \frac{1}{mn} \sum_{l=1}^{m} \sum_{j=1}^{n} D_{ij}^2 - \sigma_K^2 - \sigma_1^2$$

where D_{ij}^2 : the squared distance from a point of group $\bar{K}$ to a point of group 1,
σ_k^2, σ_1^2 : the mean squared deviations of the plots from their centroids. In the case we don't need to calculate the centroid coordinates.

The estimation of inter-group variance is equal to half of the mean squared distance between centroids. For the comparison of the inter-group and within-group variances the first must be multiplied by the size of the group. In the case of unequal group size the inter-group variance is multiplied by

$$n_o = \frac{1}{a-1} \left(\Sigma n_i - \frac{\Sigma n_i^2}{\Sigma n_i} \right)$$

where a : number of groups, n_i : the size of group i, according to Snedecor (1957). The ratio of two estimations of variance can be evaluated by Fisher F-test that allows to estimate the significance of factor-effect.

The contribution of factor into variability of vegetation is determined by the ratio of inter-group sum of squared deviations to total sum of squared deviations from general centroid. It is equivalent to calculation of correlation ratio.

The method was first applied for studing the relation between vegetation and soil types in tundras and mires of West Taimyr (Botch, Vasilevich, Ignatenko, 1970). The transects of 10 m long were laid down in 5 types of tundras and mires. They consisted of contiquous quadrats 20 x 25 cm. The long side of quadrat was situated across the transect direction. So every transect included 50 quadrats. The cover of each species was estimated. The soil trench along every transect was dug to permafrost level and the boundaries between soil types were drawn according to morphological characteristics of soil profile. The quadrats were subdivided into groups corresponding to soil types. The quadrats that occur on the boundaries between soil types were omitted,

Table 1. - Analysis of variance of vegetation in tundra zone.
(from Botch, Vasilevich, Ignatenko, 1970)

community type	the number of transect	sum of squares within soil type s	sum of squares between soil type s	total	% of variation between soil type s
polygonal mire	3	890	1290	2180	59
	10	1364	870	1234	39
wet tundra	1	1518	434	1 952	22
	4	1675	862	2537	34
spotty tundra	5	1026	379	1405	27
hummocky tundra	7	975	365	1340	27
	6	1 048	457	1 505	30
spotty tundra with cracks	2	1304	180	1 484	**12**
	8	1 011	194	1205	16

The investigated transects can be divided into three groups in relation to degree of correlation between vegetation and soil. The first group includes the transects in polygonal mire. The soil factor determines here from 39 to 59 % of vegetation variation. It results from the fact that vegetation and soil patches and related to microtopographic elements and they have larger sizes.

The second group includes the transects in hummocky, spotty and wet tundras. The differences among soil types of the group determine 15-30 % of vegetation variation only. The instability of vegetation decreases the correlation with soil.

The third group consist of the transects in spotty tundra with cracks. In this case the relation of vegetation to soil is most loose. The soil differencies don't affect vegetation significantly.

The soil and vegetation are very patchy in tundra. The size of the patches is often very small, reaching few dm. What is the influences of such micro-patchiness on our results ? To determine it we calculated the correlation ratio for lichens, mosses and vascular plants separately. But the per cent of variation that is a result of soil types differences is approximately equal for the three group of plants. It means that the penetration of vascular plants roots in the neighboring patches of soil is of little value.

By this method we carried out the one-way analysis of variance. Naturally, the following stage must be two or multivariate analysis of variance. The calculation of within-group variance can be made by the same method. But calculation of untergroup variance has some peculiarities in the case of use of two-way analysis of variance of dissimilarity coefficients.

Let us consider the following scheme. There are three classes of factor A and two of factor B.

	X_{11}	X_{12}
A	X_{21}	X_{22}
	X_{31}	X_{32}

For calculating the main effect of factor A we take into consideration square distances between centroids only that differ from each other in relation to factor A only that is $(X_{11}-X_{21})$, $(X_{11}-X_{31})$, $(X_{21}-X_{31})$, $(X_{12}-X_{22})$, $(X_{12}-X_{32})$, $(X_{22}-X_{32})$.

For calculating the main effect of factor B we take into consideration the pairs of centroids that differen in relation to factor B correspondingly. The interaction between the factors can be estimated by means of calculating the centroid distances that differ in relation to both factors simultaneously, that is $(X_{11}-X_{22})$, $(X_{12}-X_{21})$, $(X_{11}-X_{32})$, $(X_{12}-X_{31})$, $(X_{21}-X_{32})$, $(X_{22}-X_{31})$. In this way we break down the inter-group variance into three components.

The method was applied to study the effect of topographic factors on subalpine meadow vegetation in Little Caucasus (Vasilevich, Latifova, 1973). The vegetation releves were subdivided into groups in accordance with aspects and the position on the slopes. There were two aspects (northern and southern) and three positions on the slopes (upper, middle and lower). The both factors determine about 50 % of vegetation variability. It is interesting to note that factors interaction in higher than the main effects : the main effect of aspect is 12.1 %, the effect of position of the slopes 4.5 % and interaction of them 28.6 %. The fact which was known to ecologist. But we give a quantitative estimation of it.

Table 2. - Relationship of vegetation and topography in subalpine meadow vegetation. (from Vasilevich and Latifova, 1973).

Source of variation	Mean square	n°	d. f.	Sum of squares	% of variation
Aspect	17.66	33.2 x 5	1	2930	12.1
Position an the slope	3.23	33.2 x 5	2	1072	4.5
Interaction	20.87	33.2 x 5	2	6929	28.6
Within groups	10.10	5	194	9795	40.3
Within plots	4.36	-	800	3480	14.4

The within-group variation accounts for about 40 % of the vegetation variability. It affects other environmental factors that don't correlate with topography. The variation within plots that is equal to 14.4 % can be explained by effects of spatial exclusion, species acceptability and so on. It is responsible for little part of variation.

On the example of this vegetation we studied also the effects of different chemical components of upper soil layer on it. The range of every factor was subdivided into 5 classes of equal width. The factors were as follows : the humus content, nitrogen, potassium and phosphorus concentration. Each factor determines approximately equal part of variation : nitrogen - 21 %, humus - 23 %, phosphorus - 23 % and potassium - 33 %. It is known that all these factors are close correlated and as a result the simultaneous effect of these 4 factors may not exceed significantly the effect of single factor.

The method gives the possibility to relate two measures of dissimilarity, for example, the dissimilarity of vegetation and soil. We can calculate the correlation ratio between two sets of dissimilarity coefficients. It is equivalent to one-way analysis of variance. The method was used many times for evaluating effectiveness of ordination techniques (Gilbert a. Curtis, 1953 ; Bray a.

Curtis, 1957 ; Swan a. Dix, 1966). But we propose to calculate the correlation ratio and don't use correlation coefficients because the relations between dissimilarity measures can be curvilinear.

There are some troubles with estimation of degrees of freedom. The number of degrees of freedom in dissimilarity matrix is not equal to the number of the pair of objects because the rank of the matrix is not equal to its order. The equation that gives the possibility to estimate the degrees of freedom was derived by means of mathematical induction method.

$$df = (n - 2)(p + 1) - [p(p-1)/2 - 1], \; n > p$$

where n - the number of objects, p - the number of orthogonal axes in the multidimensional space (the rank of matrix). Usually we don't know the rank of the matrix. It can be estimated by principal component analysis. It is equal to the number of principal components that have a significant contribution to object variability but the work has not been done so far. Therefore we can estimate the degrees of freedom approximatively only which in many cases enough.

The method was applied for the study of the relationships between vegetation, chemical content and botanical composition of peat in some peat bog communities in the middle taiga zone of the European part of the USSR (Botch, Vasilevich, 1974). The plots were of 20 x 25 cm size and were located into transects. The peat samples were collected in every plot from the depth of 25 cm. The transect 8 was located in Sphagnum fuscum community where there are a little patches of Sphagnum magellanicum and Sphagnum angustifolium. The correlation ratio of vegetation to botanical composition of peat is equal 0.35, to chemical content - 0.28. It is interesting to note that the correlation ratio vanish if we omit 3 plots which have most dissimilar vegetation and peat with others plots.

The method has some constrains as any method. The most serious restriction is that we are not able to obtain a full set of classes of factors in many cases of natural vegetation sampling. It does not allows to accomplish a two or three way analysis of variance.

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XV - A DYNAMIC MODEL FOR CROP GROWTH RATE IN A DWARF SHRUB COMMUNITY

S. Kellom6ki, **P.** Hari and E. Vaisnnen

Department of Silviculture, University of Helsinki
Unioninkatu 40 **B,** SF-00170 Helsinki 17, Finland

The dry matter production of a bilberry (Vaccinium myrtillus L.) and cowberry (Vaccinium vitis-idaea L.) community was studied in Central Finnish conditions. A dynamic model for the crop growth rate of the community was constructed in two stages which included (1) a model for the daily height increment for both species, and (2) a model for the relationship between weight and yield for both species. The independent variables for daily height increment were the growth rhythm and the theoretical daily amount of dark respiration. The effect of temperature on crop growth rate was also discussed.

Introduction.

The production of structural dry matter by the shoot system can be divided into two parts : radial and height increment. As far as the productivity of dwarf shrubs is concerned, the radial growth is of minor importance only (cf. MAlkonen, 1974). Attention is thus focused in this study on height growth.

The amount of dry matter in a shoot is closely correlated to its length (Mblkbnen, 1974 ; Pohjonen, 1975). Thus the production of structural dry matter can be obtained from height increment measurements. This method has the following advantages :

1) the destruction of the study object is avoided
2) the height increment of the same shoots can be monitored daily
3) the method is more accurate than the harvesting method

Since certain physiological and environmental factors can be correlated with the daily height increment, it/is possible to analyze the daily production of structural dry matter. Thus the effects of self-regulation and of environmental factors on growth can be separated from each other.

The purpose of this paper is to present one way of analyzing the daily production of structural dry matter on the basis of self-regulation and environmental factors. The growth model presented in this paper is the most advanced one so far developed in the Department of Silviculture of the University of Helsinki (cf. Hari, 1968 ; Hari et al. , 1970 ; Hari, 1972 ; Pohjonen and Haris, 197.11).

Materials.

A part of the data used in preparing the present paper was collected in 1973 at the Forest Field Station of the University of Helsinki (61°51'N, 24° 20'E; 150 m a. s. I.). The plant species monotired were Vaccinium myrtillus (L.) and Vaccinium vitisidaea (L.). The height growth of ten shoots of both species were measured once a day at 8. 00 a. m, to an accuracy of 0.1 mm. The total length of the shoots for both species were converted into daily values corresponding to the stuctural biomass produced during the growing season, using the following empirical regressions :

(1) y_1 = EXP(0. 9214 x LOG X_1 - 0. 3945), R^2 = .92

(2) y_2 .= EXP(1. 4797 x LOG X_2 - 2. 9143), R^2 = . 95

where

yi = total structural biomass produced by Vaccinium myrtillus
Y2 = total structural biomass produced by Vaccinium vitis-idaea
xl = the total height of the growing shoots of Vaccinium myrtillus
x2 = the total height of the growing shoots of Vaccinium

As far as environmental variables are concerned, only the temperature was monitored. This was done using a multipoint recorder and a thermohydrograph placed at a height of 20 cm above the ground. The chart was read once every hour. The additional data used in the construction of the growth model was collected in 1974. The length increment of ten runners of Rubus saxatilis (L.) were measured in the same manner every two hours.

Model.

In the boreal zone the temperature is the most important factor affecting growth (cf. Mikola 1962, Sarvas 1972, Hari and Leikola 1974). Let t denote time, x temperature, H height and h height growth rate. The height growth rate is defined as &allows :

(3) $$h = dH/dt$$

Let ti be the beginning instance of the j:th day and gj the height increment of the j:th day.

Let us first analyze the data on the basis of the assumption that temperature is the only factor affecting growth (cf. Abram' 1972). Many researchers have observed a time lag in the effect of temperature on growth (cf. Mork 1941, Odin 1972, Worral 1973). In our Rubus saxatilis material a time lag of six hours gave the best fitness (Fig. 1).

Let us further assume, that the dependance of growth on temperature is independent of the plant species in question. Of course however, the absolute growth level varies from one plant species to another. The effect of the growth level is taken into consideration with level parameter a. When Eq. (3) is integrated from t_j to t_{j+1}, Eq. (4) is arrived at :

$$(4) \quad g_j = a \int_{t_j}^{t_j+1} h(x(t-6))dt$$

The daily height increments of Vaccinium myrtillus and values for the right hand side of Eq. (4) are depicted in Fig. 2. The time unit is 24 hours. It is evident that the fitness is fairly good in the middle of the growing period, but at the beginning and end there is increasing discrepancy. This is due to the effect of self-regulation by the plant. The model must thus be further developed and the effect of this self-regulation by the plant included in the model.
Let us denote

$$(5) \quad k_j = \int_{t_j}^{t_{j+1}} h\,(x(t-6))dt$$

Let s denote the physiological stage of development and M the rate of maturation. If the rate of maturation depends only on temperature, then s and M are connected by Eq. (6) :

$$(6) \quad s(t) = \int_{t_o}^{t} M(x(t))dt \qquad (t_o \text{ is the beginning instant of the growing season})$$

Function M can be approximated with the dependence of dark respiration on temperature (see Fig. 3). The self-regulation of the plant can now be introduced into the model using these concepts.

Let s_j denote the physiological stage at the beginning of the j:th day. Let us assume that g_j depends only on s_j, a and k_j, and that the effect is multiplicative, i. e.

$$(7) \quad g_j = f(s_j).\,a.\,k_j$$

It is evident from Fig. 2, that at the middle of the growing period function f should be equal to 1.0, and at the beginning and end of the growing period it should be approx. 0.1. Let us therefore assume that function f is of the type shown in Fig. 4. All the necessary assumptions have now been included in the model and the model can be tested with some empirical data.

Results and discussion.

The values of parameters a, a_1, s_1, s_2 and s_c were estimated by computer interation for both of the species under study. The corresponding values are presented in Table 1. The daily structural biomass values were computed for both of the plant species according to the model and then compared with the actual measurements. The results are presented in Figs. 5 and 6. The total number of growing shoots of both species per unit area of ground cover has been taken into consideration in the calculations.

Table 1. - Parameters of the growth models for Vaccinium myrtillus and Vaccinium vitis-idaea and the correlation between observed and computed values of daily production of structural biomass.

species	a	a1	Parameters s1	s2	sc	% of explained variance
Vaccinium myrtillus	14.0	0.32	2	15	36	.89
Vaccinium vitis-idaea	12.2	0.00	20	20	46	.78

The discrepancy between the observed and computed daily values of the produced structural biomass is no longer of any significance. This is in good agreement with our earlier observations concerning other plant species which include many different ferns, conifers, deciduous trees, herbs and grasses (Hari et al. in prep.). When the model was developed rather a lot of assumptions had to be made. The results, however, show that these assumptions are in quite good agreement with the actual biological situation. The model has already been applied to agricultural problems (cf. Pohjonen and Hari 1973, Pohjonen 1975), and shows much promise for further use in this field.

Temperature was the only environmental factor included in the model. This feature can best be explained by assuming that plants utilise stored carbohydrates when the daily consumption of carbohydrates exceeds the daily production of photosynthates (cf. Kotzlowski and Widget 1964, Gordon and Larson 1970, Lutzke 1972). As a result of self-regulation the effect of temperature on growth varies from one growth phase to another. The model however, has the advantage that the effects of temperature and self-regulation can be isolated from each other.

Acknowledgement.

We are very grateful to Professor Paavo Yli-Vakkuri, Head of the Department of Silviculture of the University of Helsinki, for providing the facilities used in this research project. The study project has been financed by a scholarship from the Academy of Finland.

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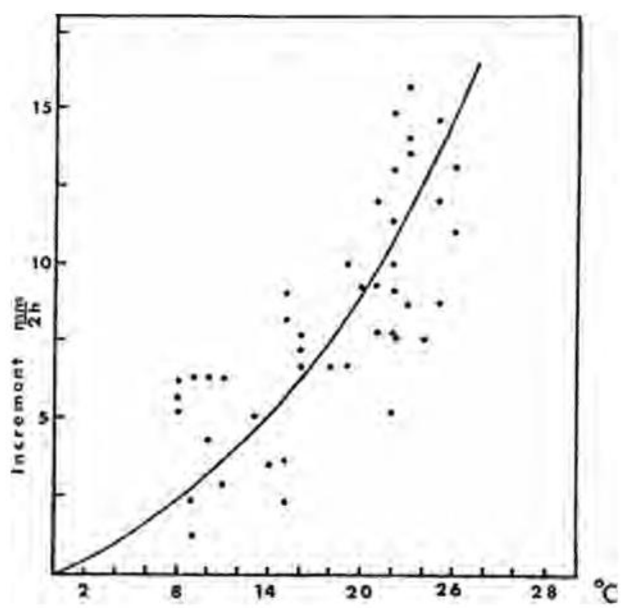

Fig. 1'. The length increment of Rubus saxatilis runners as a function of temperature with a time lag of six hours.

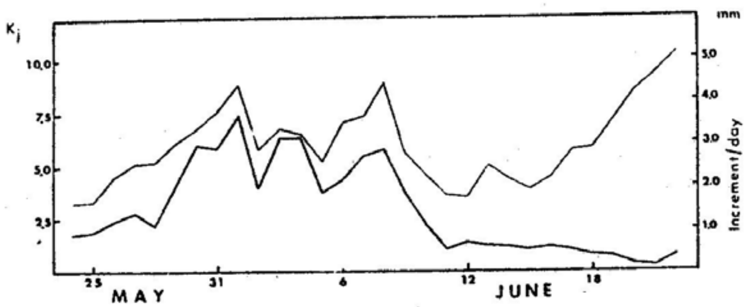

Fig. 2. Daily height increments (thick line) of *Vaccinium myrtillus* and the integrals k_j (thin line).

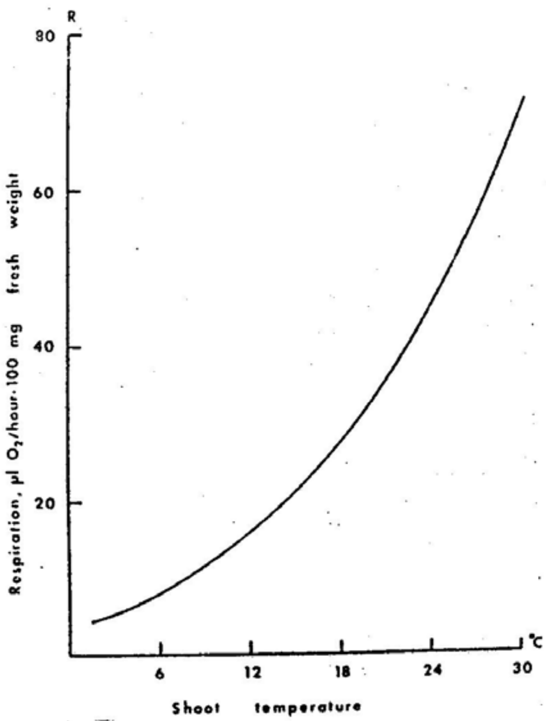

Fig. 3. Correlation between respiration and temperature in growing shoots of spruce. According to DAHL and MORK (1959)

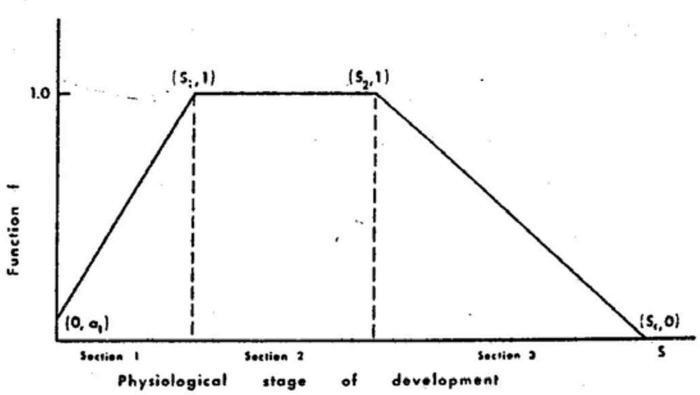

Fig. 4. The function f used in the model. The relationship between parameters a_1, s_1, s_2, and s_c, and the function f are included in the figure.

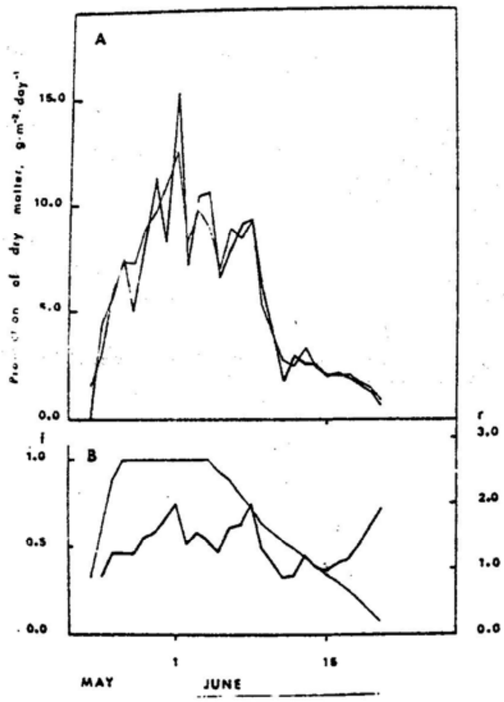

Fig. 5. The daily measured (thick line) and computed (thin line) production of structural biomass of Vaccinium myrtillus (A), and the daily values of function f and cumulative dark respiration (B).

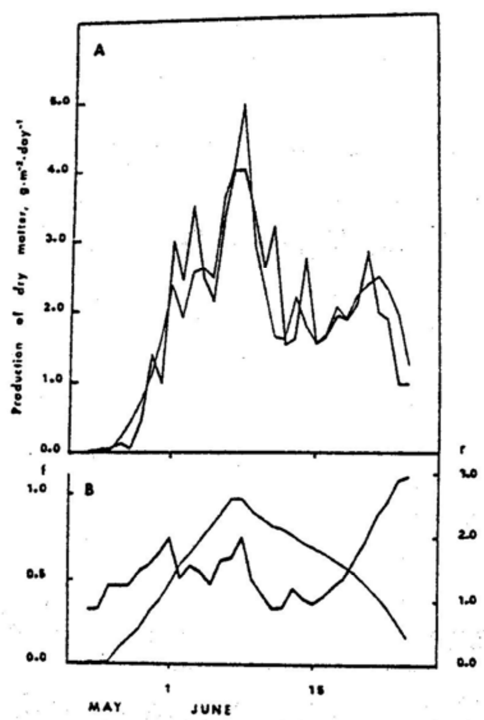

Fig. 6. The daily measured (thick line) and computed (thin line) production of structural biomass of Vaccinium vitis-idaea (A), and the daily values of function f and cumulative dark respiration (B).

XVI - INTERNATIONAL COLLOQUIUM ON FUTURE PROSPECTS IN THE PHYSIOLOGY OF FLOWERING

As part of the series of international colloquia of the Centre National de la Recherche Scientifique (CNRS) ("closed" colloquia, invited participants only) the Phytotron at Gif/Yvette is organizing from the 17th to 21st July 1978 an International Colloquium on Future Prospects in the Physiology of Flowering.

The originality of this colloquium is due to the following features :

a it will include two parts :

preliminary meetings in 6 sections who will prepare and propose their conclusions.

. a discussion between all the sections on the conclusions proposed by each section.

b - it is a colloquium on "future prospects" i. E. it is intended to be a reflection on new directions of research concerning the determination of flowering.

c - this colloquium is organized so as to allow an exchange of ideas between workers in various disciplines : physiologists, geneticists, biochemists, biophysicists, model-makers, specialists in endogenous rhythms etc.

d - the 6 working sections will be :

Group 1 : Stimulation, inhibition of flowering : morphological and physiological studies.

Group 2 : Perception, nature and complexity of transmitted signals.
Group 3 : Effect of photoperiod and phytochrome in flowering : time measurement.
Group 4 : The sequences of flower evocation.
Group 5 : Metabolism and energetics in flowering.
Group 6 : Genetic systems involved in the flowering process.

A report on the work of this colloquium will be published.

XVII - PHYTOTRON SYMPOSIUM AT THE 20th INTERNATIONAL CONGRESS ON HORTICULTURE IN SYDNEY

In issue 16 of Phytotronic Newsletter we announced the organisation in August 1978 in Sydney (Australia) of a Horticultural Phytotronic Symposium. This symposium is sponsered by the Interdisciplinary Section of the Congress whose President is M. G. Mullins.

Subjects will include all aspects of the use of results obtained in phytotronic installations related to fundamental or applied horticultural research. "Phytotronic installations" includes not only phytotrons but also rooms and variable volume cabinets with more or less complete environmental control.

Those who desire more informations please write to:

Dr. J. C. Mc FARLANE- Environmental Monitoring and Support Laboratory-
USEPA-PO Box 15027. Las Vegas. Nev 89114. USA.

XVIII - ESNA. EUROPEAN SOCIETY OF NUCLEAR METHODS IN AGRICULTURE

We received from Secretary's Office of ESNA:Proceeding 1976 which summary is given below :

ESNA-COMMITTEE-Secretariat Treasurer and sub-treasurers.

ESNA WORKING GROUPS AND CHAIRMEN

MEETING OF WORKING SUBGROUP lB IN MUNICH (RFA) 8-11 june 1976. "Waste irradiation"

ESNA SEVENTH ANNUAL MEETING,Varsaw (Poland) september 13-17 1976

Programme

Official address by Prof. S. MOSKAL
Official address by Prof. Dr. S. A. PIENIAZEK
Report of the Chairman D. De ZEEUW and the Secretary P. H. Van NIEROP ESNA and the world food crisis,by D. De ZEEUW
Resistance breeding as a method to improve environmental quality, by J. E. PARLEVLIET
Nitrogen. An essential life factor and a potential hazard for the environment ,by M. J. FRISSEL
Report of Working Group 1. Food irradiation by J. C. Van KOOIJ and J. FARKAS
Report of Working Group 2. Radiation induced stimulation effects in plants. By J. SIMON
Report of Working Group 3. Tracer techniques in animal sciences by K. CUPERLOVIC
Report of Working Group 4. Radiation analysis by W. K. G. KUHN
Report of Working Group 5. Nuclear Techniques in the study of soil. Plant relationships by M. J. FRISSEL
Report of Working Group 7. Environmental Pollution by R. KIRCHMANN
Report of Working Group 8. Nuclear methods in fast routine analysis of Biological material by E. G. NIEMANN
Report of Working Group 9. Genetical methods of pest control by R. J. WOOD
Report of Working Group 11. Nuclear methods in plant physiology by R. ANTOSZEWSKI
Meeting of **ESNA Committee. Friday** september 17th 1976. Warsaw.
List of Participants.

Those readers who desire more informations please write to :

Secretariat ESNA-ITAL. Po Box 48 Wageningen,Pays -Has.

XIX. AUTUMN AND SPRING WEATHER CONDITIONS AND WINTER PLANTS PRODUCTION

A. I. KOROVIN, E. V. MAMAEV and V. M. MOKIEVSKII

This book published in 1977 by Hydrometeoisdat-Leningrad have 160 pages and 253 references.

The experimental investigations data of the autumn and spring conditions influence upon the winter rye and wheat winter and crop production are summarized. This conditions were modelling in the experiments using the modern technical. means according to the nature weather types. The main attention is given to the analysis of the winter crops, winter and crop production dependences from the autumn and spring hydrothermic conditions. The influence of the high and low winter and spring positive temperature, winter frosts, the first autumn frosts and the late frosts, connected with the different soil moistening is studied, the lighting influence on 'the winter crops is analyzed. The questions of the nitrogen feeding as a soften mean of the extreme winter conditions negative influence are also affected.

The experiences were performed under natural culture conditions as well as in fixed or mobile growth cabinets with temperatures and humidity regulation. All factors(low temperatures, frosts, various soil humidities and mineral nutrition) were examined as to their effects on crop production.

This book, unfortunately entirely in Russian without any abstracts in other languages, includes following four chapters:

Chapter I. Experimental modelling of hygrothermic conditions during the: autumn-winter-spring period with a view to studying their affects on winter plants.

Chapter 2. Influence of autumn hygrothermic conditions on winter resistance and crop yield of winter plants.

Chapter 3. Influence of spring hygrothermic conditions on the vitality and crop production of winter plants.

Chapter 4. Influence of autumn and spring temperatures on the effectiveness of feeding supplementary nitrogen.

XX. PRINCIPLES OF THE REGULATION OF PRODUCTION PROCESSES IN AGROECOLOGICAL SYSTEMS

Editor in chief: A. A. NICHIPOROVITCH. Ed. Nauka•Moscow 1976.

This 202 pages collection is difficult to examine since it is published in Russian with no summaries in other languages. It contains 22 articles and a preface. Both theory and methods of study of processes regulating crop formation in agricultural plants are presented. Special attention IS given to research in controlled environments, the principles of optimization of growth, the formation of structural components of the crop and plant photosynthetic activity. Also studied are methods for optimizing conditions of agroecological systems in the field with the aid of programs using complex means resulting from the experiments.

Being unable to analyze the various articles we simply give a translation of the table of contents:

M. K. KAUMOV,E. D. ADINIAEV. Regulation of maize production by modification of density irrigation and fertilizers.

G. C. RUSAKOVA. Optimal length of plant culture cycle in continuous cultures.

E. V. LEBEDEVA,V. M. SMIRNOV,M. V. WILLIAMS. Technology and perspectives in potato culture in artificial media.

V. I. ROJDESVENSKY. Physiological efficiency of various artificial light sources for phytotrons.

V. N. SOKOLOVA. Automatic control of assimilation in plants by use of an oxygen sensor.

G. V. LEBESEV,V. G. EGOROV,V. G. BRUKVIN. Intermittent irrigation of cultivated plants.

I. I. SVENTIZKI. Bioenergetic•aspects of regulation of production in agroecological systems.

C. I. TRAVIN. Regulation of culture structure in obtaining high yields from leguminous cultures.

I. M. PIUNOVSKY. Principles and research methods in complex culture techniques.

P. G. RUSSKIKH,A. I. OUSKOV,V. N. SOKOLOVA. Apparatus for controlling increases in vegetable biomass (biomass-meter).

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XXI. NEW PERIODICAL

News Bulletin of British Plant Growth Regulator Group

The first issue starting on May 1977. Two bulletins per year, in May and November,are forecast. Annual subscription for July 1977-June 1978 was 5 4-.

The items included comprise: Abstracts of papers on Plant Growth Regulators. Details of forthcoming meetings-Contributed articles on topics of general interest-Information on new compounds-Short research reports-Book reviews-European news and news from the Plant Growth Regulator Working Group. News of B. PGRG members.

Those who want more information please write to: Dr. T. H. THOMAS, Secretary of BPGRG-National Vegetable Research Station. Wellesbourne-Warwick. U.K.

XXII - LIVRES NOUVEAUX - LIST OF NEW BOOKS

ARNDT T. M.,D. G. DALRYMPLE and V. W. RUTTAN Editors. Resource allocation and productivity in National and international Agricultural Research 1977. University of Minnesota Press. USA . A 25.00.

O. BEWLEY and M. BLACK. Physiology and biochemistry of Seeds in relation to germination. 1977. Springer Verlag.360 pages D. M.90.

BUVET R.,ALLEN M. J. and MASSUE T. P. Living systems as energy converters. Proceedings of the European Conference at Pont a Mousson. France 1976-1977. Ed. Elsevier 348 p. , 29,50.

Centre de Recherches Scientifiques en Biologie de l'Ac. Sc. URSS. Problemes de Photobiologie pratique. Rayonnement ultraviolet ecologique,sources,biophotometrie (en russe). Puschino 1971,160 p.

A Handbook of Agricultural Terms.1977. IBIS; New Bulding North Circular Road. Neasden London NW 10 OJG-UK.

Handbook for Plant Growth Regulators.1977. Information: Prof. R. P. UPCHURCH. Plant Sciences Dept Bld 36,University Arizona1Tucson Arisona 85721 USA.

INNIS G. S. Grassland Simulation mode1.1977. Ed. Springer Verlag.320 p. A22,80.

KHAN A. A. The Physiology and Biochemistry of seed dormancy and germination. 1977 Elsevier Ed.466 p. # 65.95.

LELLEY J. Wheat breeding: theory and practice Akademiai Kiado ed. Budapest.1976.286 p.

MARRE E. and CIFERRIO. Regulation of Cell membrane activities in plants. Proceedings of an International Workshop held in Pallarza Italy 1976. 1977. Ed. Elsevier 332 p. 32,75.

NOVER L. and MOTHES K. Cell Differentiation in Microorganisms Plants and Animals. Proceedings of the Deutsche Akademie der Naturforscher. Thuringia 1976. 1977. Ed. Elsevier 640 p. 49)75.

Progress in Botany vol.38 : Morphology,physiology,genetic,taxonomy and geobotanic. 1976. Springer Verlag Ed. Berlin 377 p. 49.20.

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M. R. SIEGEL and H. D. SISLER. Antifungal compounds. Volume 1: Discovery,Development and Uses.1977.616 p. Ed. Marcel Dekker AG. Switzerland. S. Fr.175.

TRONCHET A. La sensibilite des plantes. Ed. Masson. Paris 1977,158 p.

XXIII - ARTICLES SIGNALES. ARTICLES IN PRINT

BARTSCH J. A. and M. F. FINNER. A low temperature grain drying experiment in an artificially reproduced environment. Transactions Am. Soc. Agr. Engr.1976,19, 378-381.

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XXIV - REUNIONS ET EXPOSITIONS ANNONCEES
COMING EVENTS, MEETINGS AND EXHIBITIONS

1978 January 4-5 London (UK)
Symposium "Opportunities for Chemical Plant Growth Regulation" organized by BPGRG and British Crop Protection Council
Inquiries : Dr. E. F. George ICI Ltd . Imperial Chemical House.
Millbank London **SW** 1P 3 JF (UK)

1978 January Israel
ISHS Symposium on water supply under glass and Elastics
Inquiries : Dr. K. **M. SCHALLINGER** Inst. Of Soils and Water
The Volcani. Center. POB 6 Bet Dagan Israel .

1978 Fivrier 6-8 Quebec **(Canada)**
Congris National de Pazsage du Canada avec exposition commercial*
benseignements : Les Productions David Courtin a/s les Services GSC
Casa Postale 91. Champlain Lassalle,Quebec Canada

1978 Fevrier 22. Paris (France)
L'ecoulement des fluides biologiques.
Apres-midi d'Etudes organisee par la Section Thermobiologie de la Societe Frangaise des Thermiciens.
Renseignements: IFCE. Maison de la Thermique.3, Rue Henri Heine, 75016. Paris France.

1978 6-10 mars Toulouse (France)
Colloque international sur l'observation spatiale de la Terre *et* la gestion des ressources planetaires (OST).
Renseignements : Secretariat du Colloque OST. BP 4130. 31030. Toulouse Cedex France

1978 April 10-15 Nancy-Metz (France)
103e Congres National *des* Societes Savantes
Renseignements: BibliothAque Nationale.58 rue de Richelieu,
75084-Paris Cedex 02. ftiolm.

1978 April-May Avignon (France)
ISHS Working party on "Optimization of growth through control of the microclimate"
Inquiries: Dr. J. DAMAGNEZ INRA Station de Bioclimatologie. Domaine de St Paul Cantare1.84140. Montfavet France

1978- Mai 24 Paris (France)
La Bioconversion
Apres midi d'Etudes organisee par la Section Thermobiologie de la Socigte Francaise des Thermiciens.
Renseignements: IFCE. Maison de la Thermique,3 rue Henri Heine,
75016 Paris France

1978 May 31-June 9 Paris **(France)**
10th International Congress on Mushroom Culture
Inquiries: Secretariat 10e Congris Cbampignons comestibles
INRA Bordeaux, 33140,Pont de la Maye,France

1978 **June. Sweden or Norway**
Symposium on Landscaping of cut-off bogs Inquiries:Prof. Kuntze.
Ausseninst. Bodenkunde,Friedrich. Missler Str.46-48 2800 Bremen BRD

1978 **June** 12-16 Alnarp **(Sweden)**
Symposium on quality of vegetables (ISHS)
Inquiries: Dr. Torsten Nilsson,Department of Vegetable Crops Agricultural College of Sweden S 230 53 Alnarp (Sweden)

1978 September 4-8 Gembloux Belgique
International Study Week. Statistics and Computer Science in Agriculture
Information; Prof. P. DAGNELIE. Faculte des Sciences Agronomiques de l'Etat 5800 Gembloux Belgique.

1978 **Septembre 4-8 Gembloux Belgique**
Semaine d'itude internationale:Statietfque et informatique en Agronomie
Renseignementa: Prof. P. DAGNELIE,Faculte des Sciences Agronomiques, 5800 Gembloux Belgique

1978 **September 4-8 Wye College (UK)**
Symposium on Labour and Labour management
Inquiries: J. A. H. NICHOLSON School of Rural Economics and Related Studies Wye College Nr Ashfort Kent TN25 5 AH UK

1978 **Ootobre 18-29 Iberflora Valencia Espagne**
Inquiries: Iberflora,Apartado 13,Valencia Espagne

1978 **Brazil**
Second South American Symposium on Vegetables
Inquiries: Secretariat ISM Bezuidenhoutseweg 73 **,The Hague Netherlands**

1979 Wageningen (Netherlands)
ISHS Symposium: Computers for greenhouse environment control.
Inquiries: G. H. GERMING-IMAG. Postbox 43 Wageningen The Netherlands

1979 Littlehampton (UK)
ISHS Symposium : Nutrient film technique

1979 Avignon (France)
Multidisciplinary meeting on "Growth optimalisation through microclimate control"
Inquiries : J. DAMAGNEZ. INRA. Domaine St Pau1.84140. Montfavet France.

1979 6 mois Bundesgartenschau **BONN (FRG)**

1979 Avril 28-Octobre 17. **Prague (Tchlicoslovaquie)**
Exposition agricole

1979 **Spring SkiMiewice (Poland)**
Symposium on Growth regulators in floriculture
Inquiries: Skiezniewice Poland

March or April Trichur (India)
ISHS Symposium on Cashew nuts
Inquiries: J. G. OHLER Tropical Institute;Mauritskade 63 **Amsterdam -0- The Netherlands**

1979 July 8-13 East Lansing USA
9th International Congress on Rural Engineering organized by Michigan State University and American Society of Agricultural Engineers.
Inquiries: Prof. C. M. HANSEN CIRG Congress Coordinators 113 B Agricultural Engineering Bldg. Michigan St Univ. East Lansing Mich.48824. USA

1979 August. Aarslev (Denmark)
Production planning of Glasshouses floriculture (ISHS)
Inquiries: Dr. O. V. CHRISTENSEN,Research Institute for Glasshouse Crops Kirstinebjergvej 10,DK-5792, Aarslev,Denmark.

1979-1980 Los Banos Phillipines
Symposium on problems of vegetable research
Inquiries: Secretariat ISHS. Bezuidenhoutseweg 73,The Hague Netherlands

1980 Fed. Rep. Germany
Fifth ISHS Symposium on virus diseases of ornamental plants
Inquiries: Dr. R. KOENING Inst. Fur Virusserologie Messeweg 11/12 33 Baunschweig BRD

1980 Aarslev Denmark
Third ISHS Symposium on Flower bulbs
Inquiries: State exp. Station. Aarslev Denmark

1980 Avril Gand Belgique
Floralies gantoises

1980 6 months. Exposition nationale horticole,BAle (Suisse)

1980 Probably Lund (Sweden)
ISHS Symposium :More profitable use of Energy in Protected cultivation
Inquiries: G. H. GERMING IMAG. Potsbox 43 Wageningen . The Netherlands.

1981 Avril Ganes (Italie)
Euroflora

1982 6 months Floriades des Pays-Bas

1982 Hambourg (FRG)
21st International Horticultural Congress
Inquiries: Prof. D. FRITZ,Institut fur Gemusebau 8050 Weihenstephan-Freising/OOB, Germany, Fed. Rep.

1983 6 months IGA A Hambourg (FRG)

1984 6 months WIG Vienne (Autriche)

1985 Avril. Floralies gantoises (Belgique)

Nous remercions a l'avance,tous ceux qui nous enverront des informations ou articles que nous reproduirons,si possible,dens les prochains numAros.

We thank, in advance, all those who will be sending us reports or news to print in coming issues.

R. JACQUES and N. De BILDERLING