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PHYTOTRONICS OF SUNFLOWER (PHOTOREGIMES)

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Phytotrons are widely used in many countries to increase breeding effectiveness. Under the term of a phytotron we understand a set of buildings and equipment providing artificial climatic conditions allowing a relatively ample opportunity to control numerous factors of environment taken as a whole or separately. Phytotrons are constant lygaining importance as in order to reach new frontiers in plant breeding new qualitative changes in technology of varieties and hybrids development are required. With the look of the abovementioned conditions one could hardly hope to develop varieties with characters corresponding to the ideotypes (models) developed in the prospective breeding programmes. The phytotron at VNIIMK (Krasnodar) including climatic greenhouses with a useful area of 5500 sq.m and about 50 climatic chambers differing in size and utilization is utilized to solve the above mentioned problem. Along with the estimation of the bulk of the breeding material for resistance to Orobanche sp., downy mildew, rust and other pathogens, the incrising of the breeding material and hybridization work is carried out in the phytotron during winter period thus increasing the rate of the breeding process.

Successes achieved in effective utilization of phytotron became possible due the research on artificial environment effect on sunflower growth and development. Basing on this research general concepts were first outlined as well as general technology of plant production under artificial environmental conditions, in other words the phytotronics of oil crops.

In the sixties phytotronics was not a branch of science, it was a set of technical means utilized in research. The improvement of phytotrons, their equipment with the most modern devices, introduction of the technology for their effective utilization in breeding and

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plant production have created necessary prequisites to consider phytotronics as a separate branch of science. As for phytotronics of oil crops and particularly sunflower researches were started with studies of the effect of spectrum composition of different artificial light sources on sunflower ontogenesis. Photo-thermic factors necessary to grow normal plants and to obtain viable seed in vegetation greenhouses and climatic chambers during autumn and winter period have been studied as well. Results of these studies served as a base to optimise the regimes of artificial climatic conditions during winter period of sunflower research in the phytotron.

Under conditions of illuminated cultivation of plants which itself is part of phytotronics, the emphasis should be placed on the choice of sources artificial optical radiation or such electric lamps which possess optical and technical parameters mostly favouring the main physiological processes. Besides, lamps should not radiate an excess of heat, they should be economical, etc. These lamps should provide sufficient and photocynthetically active radiation along with low energy consumption and meet the safety requirements.

Among many types tested in VNIIMK Phytotron for their usefulness for sunflower cultivation only those lamps which had been specially developed for plant growing under illumination deserve attention. These are luminiscent lamps of types LFR-150 (USSR), Silvania 96 T 12 (USAO, 215 w, and arc-luminescent lamps of DRLF-400 type, made of thermoresistant glass with inner reflectors in the upper hemisphere. Along with the starting control equipment they are known under the brand name OT-400 ("greenhouse radiator"), their power is 400 wt. Similar lamps are made by "Phillips" under the brand name HIRG-$). Lamps DRL-2000 and metalhaloid lamps DRL-2000 have been also tested. Results of the tests on the effect of luminescent and mercury-luminescent high pressure lamps are given in Table I.

Phenologic observations on the growth and development of the plants have shown under the effect of LFR-150 lamps having the maximum radiation in blue and red region sunflower ripened earlier compared to other illumination sources. Under these conditions reduction of the vegetation period was mainly due to an earlier appearance and a faster rate of flowering and maturation stages. Productivity formation was better attained with the help of DRLF-400 and LFR-150 lamps. Sunflower plants accumulated the highest above ground mass the seeds being the major component.

TABLE I

Effect of different lamp types on the growth and productivity of sunflower variety Peredovik (per one plant).

Lamp type	Max. spectr. part	Veget. per., days	Plant height cm	Leaf area sq. cm	Dry veget. mass, g	Seed mass g	Seed number per head		Mass of 1.000 seeds
							Total	Full qual. %	g
DRLF-400 400 wt	blue green	86	119	4746	133	45	1516	64	47
LFR-150 150 wt	blue red	76	119	4788	121	44	1786	64	36
Silvania 215 wt	blue yellow	97	128	5164	97	31	1545	50	41
		LSD 0.05 = 6.3							

Note: Above listed lamps gave approximaly the same rate of illumination (30 ± 5 KCL)

Planting qualities (germination energy, rate of germination etc.) of this seed obtained under artificial environment were similar to those obtained under field conditions.

Different illumination sources definitely influenced the biochemical composition of the seed (Table 2).

Under artificial illumination conditions with different lamps some variation was observed concerning seed oil content, fatty acid composition, the latter largely fluctuated mainly due to proportional variations between unsaturated fatty acids —oleic and linoleic. Comparing the proportion of these fatty acids in the oil of the seed obtained under natural conditions and artificial ones, in the latter case we can observe the tendency of the oleic acid to increase at the expense of linoleic acid.

To cultivate sunflower under artificial illumination lamps DRL-2000 can be utilised. Being tested for this purpose they have shown the possibility to be utilized in large controlled environment cham-

TABLE 2

Oil content and fatty acid composition of seeds grown under different illumination sources.

Lamp type	Seed oil cont. %	Fatty acid composition, %			
		palmitic	stearic	oleic	linoleic
DRLF-400	49.5	4.2	3.0	57.7	35.1
LFR-150	50.1	3.8	3.4	66.6	26.2
Silvania	47.1	3.7	3.3	58.4	34.7
Natural conditions	53.3	5.6	6.5	19.1	67.0

bers where there is a possibility to reduce high temperatures created by heat radiation by these lamps.

In our experiments though the conditions for vegetative growth and development of sunflower plants under metalhaloid lamps were favourable compared to lamps DRLF-40) in a larger degree, full quality seeds were poorly formed in heads. High rate of empty seedeness bareness (up to 80%) was observed in plants grown under powerful metalhaloid lamps (6000 wt) because of the fact that during flowering temperature in the chamber raised up to 37° C. During this stage deviations from normal flowering were observed: corollas of tubular florets did not open, pollen was not shed. Photo-thermic conditions of growing also influenced pigment content of sunflower leaves (Table 3).

Reduction of chlorophyll content in leaves in the varients utilizing more powerful metalhaloid lamps may be explained not only by the effect of the more powerful and active radiation but by the effect of high temperatures.

Thus, in controlled environment chambers it's possible to utilize luminescent lamps of LFR-150 type, mercury lamps of high pressure DRLF-400 type and metalhaloid lamps of moderate power rating considering means of reduction of their heat radiation.

The next important component of phytotronics when developing illumination regimes for sunflower growing under controlled environment consists in optimization of irradiation of plants. We have started this research by determining the lowest radiation level in the region of physiologically active radiation (PAR) crated by artificial sources at which growth and development of plants are depressed.

TABLE 3

Chlorophyll content of sunflower leaves grown under different illumination sources.

Lamp types	Max. spectrum part	Chlorophyll content in mg/10 parts of raw matter		
		A	B	Sum
Metal-haloid, 6000 wt	violet, yellow, red	13.38	6.73	20.11
Metal-haloid, 2000 wt	blue, green, red	18.49	7.58	26.07
Mercury (DRLF) 400 wt	blue green	19.77	6.87	26.64

Note: Abovelisted lamps created approximately the same illumination (40 ± 50 KCL)

Studying growth processes under radiation conditions of 100, 70 and 40 wt/sq.m we have found that sunflower vegetation period (va-riet-y Peredovik) under different radiation conditions lasted from 73 to 84 days. The analysis of experimental data has shown that there is a close relationship between the plant radiation level and seed yield (Table 4). For example, a 2.5 times increase in radiation resulted in a 5-fold increase in number and mass of seed per plant and almost a 4-fold increase of the dry above ground mass.

It is known that the illumination factor, particularly the radiation level significantly influences the metabolic processes in the plant and as a result affects the accumulation of storage substances in seed.

In our experiment the reduction of the radiation level resulted in the reduction of the seed oil content.

Hence, in optimizing the illumination regime for growing sunflower totally under artificial illumination one should bear in mind that the radiation level of 100 qt/sq.m (illumination 25 Kcal) represents the lowest limit beyond which plants are depressed.

Basing on experimental data on te effect of radiation on the growth and productivity of sunflower we can assume an optimum radiation whithin the range 100-200 wt/sq.m (illuminat ion 25-50 Kcal). For the sake of energy economy it is recommended to set the upper radiation limit in the controlled environment chambers during the stage of formation (5 pairs of true leaves) and seed filling.

TABLE 4

Sunflower productivity in relation to radiation level by DRL lamps (average per one plant).

Radiation level, wt/sq.m	Seed number Full total quality	included %	Seed mass g	1000 seeds mass,	Seed oil content, %
100	1494	56	34.6	41.5	48.9
70	1175	52	18.2	29.4	44.3
40	884	36	7.3	23.2	37.1
$LSD_{00,5}$= 4.6					

Having determined the optimum radiation of plants we had to study the effect of period of radiation on sunflower growth and productivity in order to optimize this parameter of artificial environment.

Results of a series of experiments studying sunflower reaction (variety Peredovik) to different photoperiods at the same lenght of darkness and to different periods of darkness at a same photoperiod in different daily cycles have shown that growing sunflower in controlled environment chambers neither the short 12-h photoperiod, nor the round-the-clock illumination distributed the process of plant transition from the vegetative into the generative state. Plants flowered and fruited, though the lenght of illumination and darkness periods in the daily cycle influenced the yield level, dry above ground mass accumulation, kernal oil content and oil composition. The most favourable conditions for yield formation in sunflower should be assumed to be 20-h day with the "light: darkness" ratio 12:8 and 16:4, and also 24-h day with "light:darkness" ratio 16:8. Continuous illumination is not recommended for practical utilization due to the fact that it did not give significant advantages for productivity increase and showed large expenses for electrical energy.

Illumination regime in greenhouses: During autumn-winter period the intensity of solar radiation, the astronomic day lenght and the day length of solar radiation are abruptly reduced.

At the same time the spectral composition of the radiation is changed. In the greenhouses, due to shading from different metal components and dirt coating of glasses illumination is further reduced by 40-60% compared to the open. That is why it is very difficult to grow full quality sunflower plants in the greenhouses during autumn and winter without additional artificial illumination.

Studies conducted by the Controlled Environment Department of VNIIMK have shown that grow sunflower under artificial illumination it is necessary and it is recomended to utilize mercury high pressure lamps of DRL type and of different power. In the phytotron greenhouses where additional illumination is achieved by lamps DRLF-400 rated for 260 wt of installed power per 1 sq.meter of the area, the illumination rate reaches 7-10 K-lux. In certain greehouses more powerful lamps are used for additional illumination; (BRL-700, DRL-1000); in the latter case the rate of illumination increases up to 25-40 K-lux, thus improving conditions for sunflower growth and yield formation.

The photoperiod length during sunflower vegetation should be at least 16 hours per day. In the greehouses this is achieved by the combination of natural and additional artificial illumination. The amount of additional illumination depends upon the astronomical day length during autumn, winter and spring periods. It is better to distribute the additional illumination during the day, for example, in the morning and in the evening. The minimum distance from the maps to the plant top level should be 0.5 m, thus eliminating the excess heating and leaf burning and improving the plant uniform illumination.

In order not to disturb the normal flowering process of plants in the greenhouses care should be taken to switch on additional lights simultaneously in neighbouring greenhouses.