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Devices Used in Radiation of Cultivated Plants

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ABSTRACT: in this article it is stated that the main task of agriculture of the republic is to meet the demand of the population for fresh vegetables throughout the year, and that such invaluable vegetables: tomatoes, cucumbers and various greens can be grown only in greenhouses or in the autumn-winter-spring period.

KEYWORDS AND PHRASES: Plants, lighting devices, optical light, stationary, portable, moving, linear radiation.

In greenhouses, in the autumn-winter-spring period, when natural radiation is not enough for the normal growth of plants, irradiation devices are used, and they are used to perform the following tasks:

- 1) when getting seedlings of tomorrow's vegetables in the spring;
- 2) prolonging the daylight by using sunlight in the cultivation of vegetables;
- 3) in the cultivation of green fodder for livestock;
- 4) Vegetable plants to get a large amount of blue mass on the stem in accelerated cultivation;
- 5) when growing vegetables in the absence of sunlight at all;
- 6) Growing flowers in the autumn-winter-spring period of the year and their in managing flowering periods.

Irradiation devices can also be used for other purposes, for example, in accelerating the growth of tree seedlings and in selection work. Recently, it is widely used in scientific research, such as selection, physiology, genetics, testing of plant varieties in extreme microclimate conditions in facilities and equipment for scientific research. Such devices speed up the experimental work several times, which allows the results to be widely applied in practice.

An example of this is the phytotron, which operates on the basis of the Scientific Research Institute of Breeding and Seed Production, which operates in the country. With its help, scientists are widely used in the cultivation of new varieties of cotton and other industrial plants.

Analysis of spectral characteristics of optical light sources used in irradiation of plants. References on electrical sources of optical rays are given in the literature for their lighting - technical characteristics in the system of light magnitudes, so they can not be used to calculate greenhouse lighting devices.

One of the main indicators of a radiation source is the photocurrent, which can be determined as follows.

A graph of the relative spectral intensity of a radiation source (Pic. 1, curve 1) is usually given in relative units. To find its scale, the ordinate of curve 1 is multiplied by the coefficient of relative spectral sensitivity of the corresponding human eye (Pic. 1, curve 2) and the curve 2 is obtained. The area bounded by the curve 2 and the abscissa axis determines the value of the luminous flux expressed in watts of the source on a scale of some m:

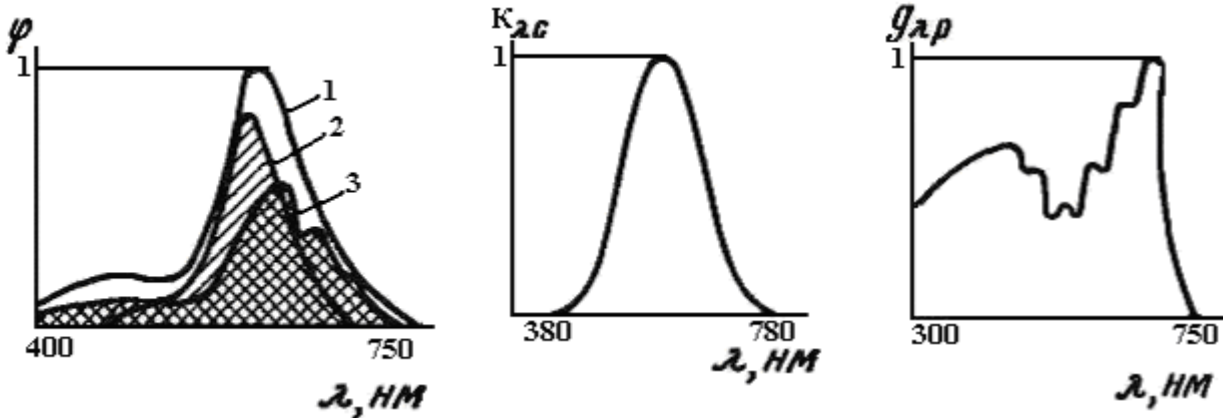
$$(1) \quad F = \int_{380}^{760} \varphi(\lambda) K(\lambda)_c d\lambda.$$

The value of the light flux of the source in lumens is determined by the following formula:

$$(2) \quad F = 680 \int_0^{\infty} \varphi(\lambda) K(\lambda)_c d\lambda.$$

The scale of the area between the curve 2 and the abscissa axis,

$$(3) \quad m = \frac{F}{680S_2}.$$



Picture 1. Relating to the analysis of the spectral characteristics of a radiation source.

The magnitude of F expressed in lumens is obtained from the catalogs, and the area S_2 is obtained by planimetry of the area bounded by the 2nd curve and the abscissa axis. To obtain the phytochemical size of this radiation source, the ordinate of curve 1 must be multiplied by the coefficient $g_{\lambda p}$ of relative spectral sensitivity of the plant leaf (curve in Picture 1), $g(\lambda)_p$ as well as the area formed by the obtained curve 3 and the coordinate axes. At a defined scale, this field represents the magnitude of F_f sought in watts or in fit according to phytocurrent units. The total irradiance of the source PR Profitability Ratio. ($Ft \text{ Wt}^{-1}$) in this case is determined from the following expression:

$$4) \quad \eta_{\phi} = \frac{\int_{380}^{760} \varphi(\lambda)_p d\lambda}{\int_0^{\infty} \varphi(\lambda) d\lambda}.$$

η_{ϕ} numerical values of magnitude are determined by the ratio S_3 / S_1 , where S_3 is the area bounded by the -3-curve and the abscissa axis; The area bounded by the S_1 -1 curve and the abscissa axis.

The following coefficient can be used to switch from the size of the lighting system to the effective sizes:

$$5) \quad K_{\phi} = \frac{F_{\phi}}{F}$$

where F_f is the Phyto flow; Luminous flux measured in F-lumen.

The efficiency of a radiation source in terms of energy costs is represented by its phytuberin size ($Ft \cdot Vt^{-1}$):

$$6) \quad H_{\phi} = \frac{F_{\phi}}{P}$$

Where the power of the radiation source, including losses in the R-starter.

Spectral characteristics of radiation sources used in greenhouses 1.6. and shown in Pictures 1.8. Their analysis shows that for irradiators with the same structure and based on fluorescent lamps, the difference in the level of phytonurization of plants is only 50... 80% due to the different power and spectral composition of the lamps only when the specific power and other conditions are equal. The effect of various other factors, such as the distance from the radiation source to the plant, causes the phytonutrient levels in plants to differ by two or more times at the same specific energies. This means that in the current and designed devices, the electricity consumption for irradiating plants under given conditions will exceed the minimum value by as many times.



It should be noted that radiation sources are very important indicators (η_{ϕ}, H_{ϕ}), and these indicators are not considered leaders in their selection and evaluation. In addition to them, it is necessary to take into account the useful life, the cost of the source, operating costs and other indicators.

When choosing the types of radiation sources for the lighting device should pay close attention to the characteristics of use of sources, ie specific operating conditions in greenhouses: high humidity and temperature, changes in voltage from the nominal value, moisture in the lamp bulb when watering plants, electric shock to service personnel extremely dangerous conditions.

The structure of greenhouse lighting devices and their requirements

The level of radiation required for the normal development and formation of plants grown under artificial conditions, if we conditionally denote it in units of light magnitude, should be at least 6... 8 thousand lux. This is ten times or more than the standard illumination in normal lighting fixtures.

To create such a high level of radiation requires an increase in the set specific power values of the radiation source, i.e. 400 W m⁻² and above. Such high-power sources are not found in lighting fixtures. In addition, the reference materials created, the methods of design of existing computing and lighting devices are not suitable for the design of lighting devices in greenhouses.

The lighting devices currently in use will vary depending on the design and the type of radiation source used.

In principle, irradiation devices can use different types of sources with a wavelength of radiation from 300 nm to 760 nm. However, as mentioned above, their effectiveness will be different. In addition, their use characteristics in specific environmental conditions of greenhouses have different effects on service life and reliability. Currently, the industry produces several different types of optical radiation sources designed to irradiate artificially grown plants.

Depending on the conditions of use of greenhouse lighting devices can be divided into:

- 1) stationary;
- 2) portable;
- 3) Movable.

Typically, stationary devices use gas discharge radiation sources in large power units. Such devices are less expensive to maintain and accordingly the technical staff will like them. However, such devices require a much larger installed capacity than portable devices. Stationary devices based on special low-pressure gas discharge lamps for botany are more effective, but at the same time their shortcomings should be taken into account, ie instead of a single lamp with a capacity of 1000 W, it is necessary to install 20... 30 low pressure lamps, which makes it difficult to use .

Portable devices reduce the installed power by at least twice when irradiating plants in the same area under any equal conditions, so a single device can be used to irradiate plants at different times of the day, in two or more plots, respectively. In doing so, the structure of those devices is more complex than that of stationary ones because they have the additional equipment needed to move from one site to another. Low as well as high pressure gas discharge lamps can be used when growing seedlings with this type of device.

When we use mobile devices, it is possible to further improve the lighting conditions of plants by distributing the radiation evenly across the surface of the plants.

Given the use of lighting devices in the greenhouse, they have a number of special requirements, namely:

1. The spectral composition of the radiant energy should be suitable for carrying out the process of photosynthesis and should not contain rays that adversely affect the development of plants.
2. The radiation should be evenly distributed on the surface of the plants and its energy should be sufficient for it to undergo the main process for plant development and crop formation.
3. The device should not overheat the plants and interfere with their processing.
4. The use of the irradiation device should be cost-effective.
5. The construction and operation of the lighting device must meet the requirements for the use of electrical equipment in rooms with a high risk of electric shock to service personnel.

Basic procedures for calculating lighting devices in greenhouses.

At present, the practice of designing lighting devices in botany is based on the normative specific power of the radiation source per square meter of irradiated surface. One of the notable disadvantages of this method is that the standard of specific power of the radiation source is accepted as the main criterion, but it cannot determine the degree of effective exposure of irradiators to plants, because the efficiency of the device at a given specific power depends on the following factors:

- a) spectral composition of radiation of the applied sources;
- b) efficient source of light;
- c) the distance between the radiation source and the plants;
- g) design of the lighting device.

The following should be taken into account when calculating greenhouse lighting devices:

1. The sharp difference in the relative spectral sensitivity curves of plants and the human eye negates the possibility of using light quantities and their units of measurement in calculations.
2. The current effective size system is not generally accepted for green plants.
3. Sharp differences in the spectral characteristics of the sources used could not assess the degree of their effectiveness, which would require a special analysis of their spectral characteristics.
4. The reliefs of plant surfaces are complex volumetric objects, so it is more accurate to describe the level of radiation as the value of the average spherical irradiance.

The average spherical radiation is numerically equal to the density of the average flux of radiation incident on the surface of the sphere with a small radius, the center of which is lost. The distribution of radiation along the surface of the sphere can be shown graphically. It can be seen that the nature of the radiation distribution is determined by the geometric properties of the illuminator.

The spherical irradiance of a point source (Pic. 2, a) at a given point on the sphere is determined by the following expression:

7) $\epsilon_{cp} = \epsilon_{\perp} \cos \psi$ where is ψ the angle between the normal and straight line at a given point of the sphere, connecting the center of the sphere with the source;

ϵ_{\perp} - irradiance of the sphere section directed to the illuminator, Ft m⁻².



Picture 2. Spherical radiation of different types of irradiators Identification.

By placing the center of the sphere at the beginning of the polar coordinates, we place the values of the radii determined from expression (7) along the radius at the accepted scales. Combining the ends of the separated pieces with a curved line, we obtain a circle based on expression (7) (The whole line in Pic. 2 a).

In practice, it is necessary to know the average value of spherical radiation. The ratios between the maximum and average spherical radii on the surface of a sphere of small radius disappearing in a point irradiator are as follows:

$$8) \epsilon_{cp, cp} = \frac{\epsilon_{max}}{4}$$

If the irradiator is a flat irradiated upper hemisphere (Pic. B), then the spherical irradiance is determined from the following expression:

$$9) \epsilon_{cp} = \epsilon_{\perp} \cos^2 \psi$$

Where is ψ the angle between the vertical and the normal at a given point on the sphere.

For this case, the description of the distribution of radiation along the surface of the sphere is indicated by a continuous line. This distribution of radiation occurs in a flat dense cloud under natural conditions. In this case, the ratios between the average spherical radiation and the maximum are as follows:

$$10) \epsilon_{cp, cp} = \frac{\epsilon_{max}}{2}$$

If the illuminator is a flat irradiated sphere (Pic. 2, c), the spherical irradiance will be the same in all directions. The distribution curves of the spherical and mean spherical radii coincide and form the center of the circle corresponding to the center of the sphere. For this situation

$$11) \mathcal{E}_{c\phi,sp} = \mathcal{E}_{max}$$

To date, standardization issues for spherical radiation have not been sufficiently developed. Therefore, the concept of horizontal radiation is used for most cases.

In calculating irradiation devices, it is important to take into account the intensity of the consumer's primary reaction to optical radiation. As such, it is possible to accept the spectral sensitivity of the middle leaf of the plant.

Calculation of point radiation source lighting devices.

When creating lighting devices that use point luminaires and standard luminaires that symmetrically distribute the flow of radiation in space, it is difficult in practice to ensure that the radiation is evenly distributed over the irradiated surface. It is also possible to create lighting devices to illuminate minimal surfaces where the degree of unevenness is obvious.

The location of the irradiators is determined by the spatial distribution of their radiation flux and the basic dimensions of the irradiated area.

The height at which the luminaires are mounted on plants depends on the type of radiation source and is determined by whether they provide a given level of irradiation and do not heat the plants (usually stationary devices with spot irradiators $h > 0.5$ m).

It is advisable to carry out calculations on the minimum irradiance, where the minimum irradiance coefficient

$$Z = \frac{E_{\phi, \min}}{E_{\phi, \max}}$$

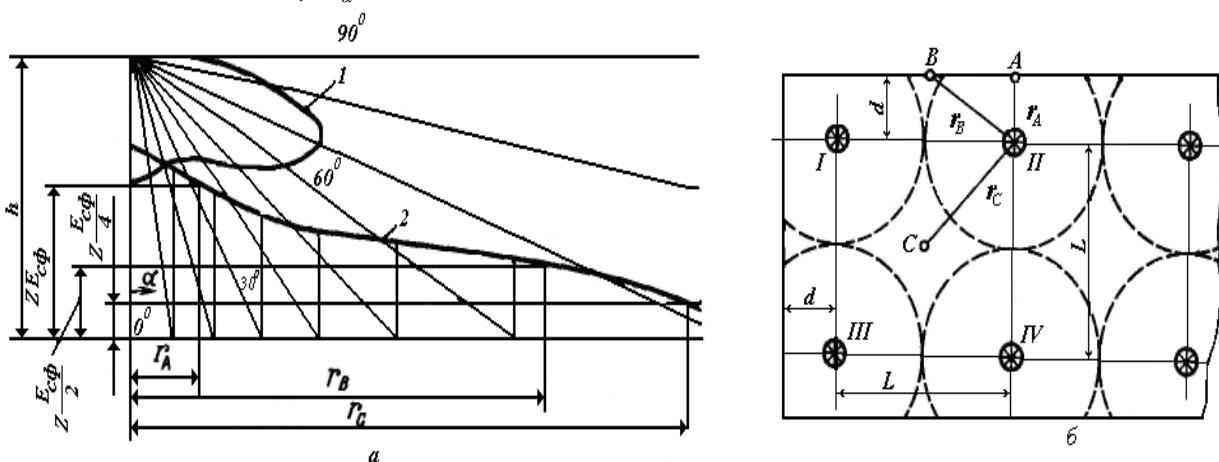
which should not be less than 0.8.

3, in Pic. A, h and r have the same scale. Using the spatial distribution curve of the received luminous flux (curve 3, a, Pic. 1), as a function of the distance r at $h = \text{const}$, the radiation distribution curves generated by it are constructed (Pic. 3, a, Pic. 2, curve 2). For different values of the distance r , the ordinate of the curve sought is calculated by the following expression:

for horizontal radiation

$$12) E_{\phi} = I_{\alpha} \cos \alpha (l_{\alpha} m_i)^{-2} K_{\phi}$$

where is I_{α} the luminous intensity at the angle determined by the spatial distribution curves α of the radiation flux of the received luminaire, kd; l_{α} - the distance from the center of light of the illuminator in the drawing to the point where the radiation is calculated; $m_i - l_{\alpha}$ - the scale of.



Picture 3. Regarding the calculation of spot radiation devices: a-compilation of radiation distribution characteristics along the rack; b-Place the luminaires on the rack surface and find the smallest allowable distance between them.

For spherical radiation

$$13) E_{\phi, c\phi} = I_{\alpha} 0,25(l_{\alpha} m_i)^{-2} K_{\phi}$$

The calculation of spherical radiation is performed as follows.

By placing the luminaires on a rack surface, they find characteristic points where the irradiance is minimal.3, Pic. B shows the placement of the luminaires at the ends of the squares as an example. Assume that points A, B, and C have the lowest value under irradiance conditions. At these points $E_{c\phi} \geq E_{c\phi, \max} Z$

A, V, S from the surface II illuminator to ensure that the condition is met (r_A, r_B, r_C)

find the maximum allowable distance to the points. For this $E_{c\phi} = f(r)$ curvature (Pic. 3, a, curve 2)

$$E_{Ac\phi} \geq E_{c\phi, \max} Z$$

The value of rA is determined when I point III, the effect of the additional radiation coming from the I and III luminaires can be taken into account after the luminaires have been fully placed on the rack surface.

At the characteristic points V and S when selecting the maximum distance L between the luminaires

$E_{c\phi} \geq E_{c\phi, \max} Z$ the condition must be met. To do this, from the 2nd curve $E_{c\phi, B} = E_{c\phi, \max} \cdot Z / 2 r_b$ and

$E_{c\phi, B} = E_{c\phi, \max} \cdot Z / 4 r_c$ is determined when The distance you are looking for $L = 2\sqrt{r_B^2 - d^2}$ or he

$$L = r_C^4 \sqrt{2}$$

The smaller of the two values of L is taken as the maximum allowable distance between the luminaires at the square end. Thus the calculation of the luminaires can be carried out in the same way even when they are placed differently.

Linear radiation source lighting devices

calculation

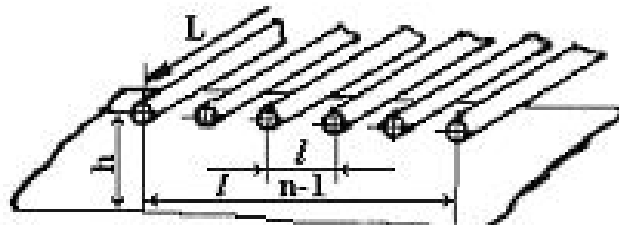
A large number of horizontally placed fluorescent lamps are used in mobile and stationary lighting devices. They are installed at a small distance from the radiation surface (0.05... 0.25 m).

When designing such lighting devices, it is important to calculate the average radiation in the area within a certain limit, for example, 1 m in width and length equal to the length of the fluorescent lamp used in the device itself. The current flowing from a row of fluorescent lamps (blocks) to the irradiated surface is not equal to the sum of the fluxes of the lamps due to the total current absorbed by the surrounding space and the side lamps.

The horizontal irradiance under the lamp block (Pic. 4) can be found in this expression 14)

$$E_{\phi} = \frac{F_n K_{\phi}}{Ll} (n - 1) \eta_{\phi, \delta n}$$

Where F_1 is the luminous flux of a single lamp of the type and power taken into account in the calculation, lm; L- fluorescent lamp length, m; - width of the lamp block equal to 1 m; n is the number of lamps in the block ($n > 1$); - the efficiency of the lamp block, which depends on the value of the total current in the ambient space and the loss of radiation flux from the lamps as a result of absorption by the side lamps.



Picture 4. On the rack surface of the block of fluorescent lamps

to calculate the radiation generated.

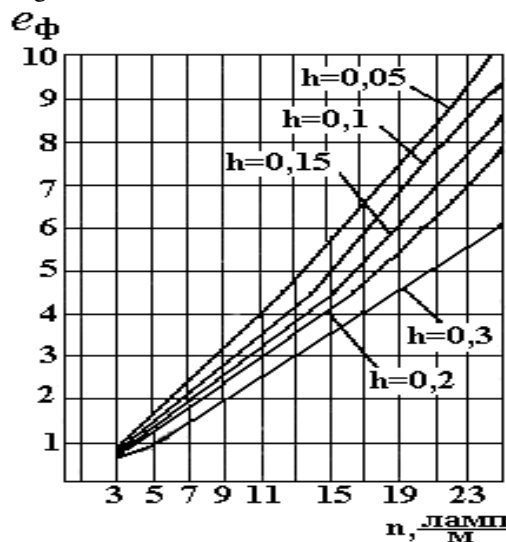
The fraction to the right of expression (14) is a constant size for this type of fluorescent lamp and can be replaced accordingly, in which expression (14) can be written as manna:



15) $E_{\phi} = \mu \cdot e_{\phi}$, in this $\mu = F_n K_{\phi} / Ll$ the catalog data of the radiation source and the constant size depending on the width of the irradiated area; $e_{\phi} = (n - 1)\eta_{\phi n}$ relative radiation, this magnitude depends on the height h and the number of fluorescent lamps in the block, but does not depend on the light-technical characteristics of the lamp.

(15) using the expression and the reference graph (Picture 5) $e_{\phi} = f(n)$

it is possible to determine the number of fluorescent lamps in a block of width 1m required to provide the required illumination. To do this, select the type and power of fluorescent lamps and calculate the value. Relative radiation, taking into account the required radiation $e_{\phi} = E_{\phi,z} / \mu$ is calculated. From the graph of the dependence of the relative radiation (Pic. 5), the relative number of lamps and the height of their placement on the irradiated surface, the number of fluorescent lamps sought is determined.



Picture 5. Relative illumination to the number of lamps in the block and to the height of their position relative to the irradiated surface

dependence If the calculations are carried out on the average spherical radiation, and the irradiators are located in the horizontal plane, then the irradiance over large areas is determined by the following expression:

$$16) E_{\phi, \text{сф}} = (0,57 \dots 0,67) E_{\phi, z}$$

CONCLUSION

1. Seedlings and vegetables can be grown in spring and autumn by providing artificial lighting to plants from irradiators.
2. The use of irradiation device should be cost effective.
3. When choosing the types of radiation sources for the lighting device, serious attention should be paid to the characteristics of the use of sources
4. The level of radiation required for the normal development and formation of plants grown under artificial conditions, if we define it conditionally in units of light magnitude, should be at least 6... 8 thousand lux illumination.
5. Methods of calculation of irradiation devices are shown

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