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ENERGY EFFICIENT LIGHT SOURCES FOR GREENHOUSES CONDITIONS

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The article deals with energy efficient light sources, especially the use of various types of artificial lighting sources using light exposure modes, with the spectral and power characteristics that really suitable for the conditions of formation of a full crop in terms of glass. Different light sources advantages and disadvantages that used for photoculture plants are presented. Emission spectrum of different types of light sources such as incandescent lamps, discharge lamps, low pressure and high pressure discharge lamps are shown. Lamps emission spectrum requirements under the impact of different spectrum parts radiation on growth and development of tomato and cucumber are presented. The main characteristics of high pressure sodium lamps of various types have been given. Illuminating characteristics dependent on structural parameters and dependence on energy luminous flux and luminous efficiency of the lamp power density is justified. The calculation of the high-intensity light sources efficiency in the areas of photosynthesis active radiation has been presented. Tips for light sources choosing, their amount to the cultivation of cucumbers, tomatoes, sprouts conditions in closed ground are recommended. The most efficient light source for greenhouses conditions are recommended.

Keywords: the light, the spectrum, the lamp, plants.

The optical radiation (OR) using under closed ground is one of the most important crop production productivity reserves [1].

The intensity and OR spectral composition changing affect the structural and functional photosynthetic apparatus organization, focus metabolic and morphogenesis of plants [2]. Energy metabolism needs plenty of pigments [9], which absorb a significant part of photosynthetically active radiation in the region of the spectrum (380-760nm). Unlike energy exchange photoregulation reaction can be carried out using a small amount of pigment that absorbs a fraction of incident light. Therefore, a comprehensive OR assessment impact as separate and different spectral plots combinations [12] photosynthetic active radiation (PAR) on photosynthetic activity of communities throughout the growing season using light mode radiation with the spectral and power characteristics that really suitable for the formation conditions of full harvest is important.

Studies and publications analysis. Today a wide range of light sources such as: incandescent lamps, discharge lamps, low pressure, high pressure discharge lamps, each source has it's spectrum emission and differently plants growth affects are used to plants photoculture.

Incandescent lamps due to there low efficiency are not widely used [1], but to increase the share of red radiation can be used in joint operation with other light sources. Lamps' spectrum is shown in Fig.1a.

Low pressure discharge lamps (fluorescent lamps) have relatively high luminous efficiency and opportunities of spectral radiation regulation through the different phosphors using. Lifetime of lamps is 10-15 times higher than the figure for incandescent lamps and includes 12000-15000 hours. The main disadvantage of this type of lamps is low power unit that requires a large number of tubes [1]. The some types of fluorescent lamps emission spectrum are shown in Fig.1c.

High pressure discharge lamps (xenon, mercury, metal halide, sodium). These lamps due to the high light efficiency and durability became the most widely used.

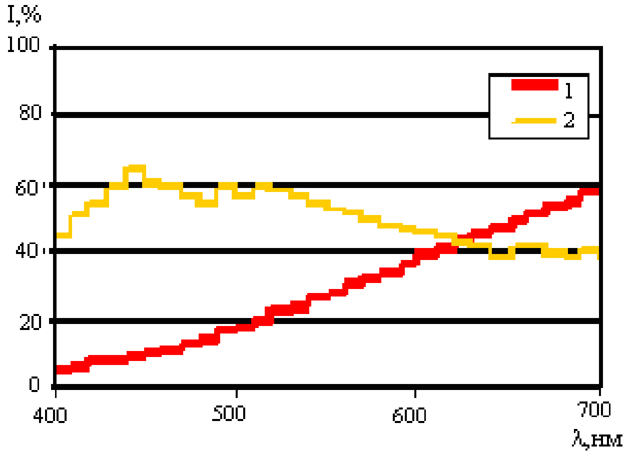
High intensity xenon lamps have emission spectrum that is closest to the sun reminds all sources (Fig.1b). The main disadvantage of these lamps is a relatively low efficiency coefficient (EC), it is only 1.5-2 times the efficiency of incandescent lamps. Lamps have low lifetime from 500 hours to 2000 [1].

High pressure mercury lamps with phosphor coating on the bulb. Lamps have line spectrum with large intervals between the lines. The maximum radiation falls on a green and blue spectrum. Due to the lack of radiation in the red (640-680nm) region of the spectrum they are not suitable for growing plants under artificial irradiation. Studies have shown that wheat plants which were irradiated with the lamp will not pour the grain, alfalfa, oats, tomatoes, peppers and others will grow badly. [9] But these lamps find wide use for lighting seedlings of tomatoes and cucumbers in the greenhouses as a source of blue-violet radiation which is not the solar spectrum in winter [4]. Sprouts that are grown using these lamps have short stems and petioles, increased plate sheet high in chlorophyll. Lamps have low efficiency for PAR-12%. DRLF lamps type are reliable, their working term is 10000-12000 hours, they have relatively high stability range of radiation which will not significantly change when the default mode, voltage and lifetime. The spectrum of these lamps is shown in Fig.1b.

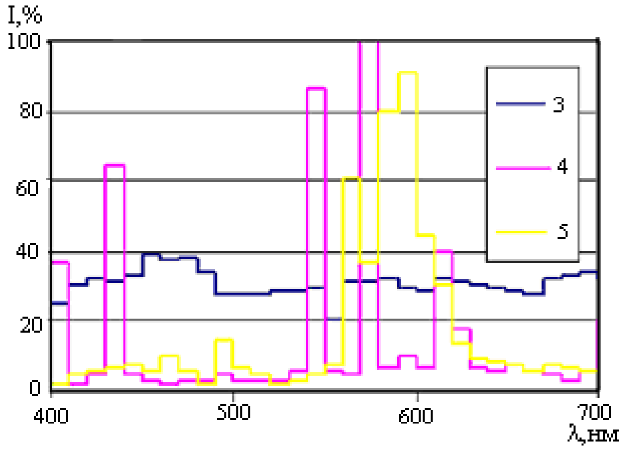
High pressure metal halide lamps (MHL) have extremely good opportunities in radiation spectrum regulation by introducing the category of different elements. For today, MHL for plant growing are developed and produced almost by all the leading firms. The efficiency of these lamps in PAR reaches 20-25% effective at sufficiently spectral composition of radiation Fig.1d. The main disadvantage of these lamps is low light settings stability during use, dependence and spectral efficiency of radiation from the power supply voltage (from the power consumption, which determines the thermal conditions and under pressure vapor emitting elements in the discharge tube). MHL are relatively small, both discharge lamps, their life period is 4000-6000 hours. The most typical MHL produced in industrial quantities are filling metal halides are three types: Na, Tl, In; Na, Sc halides and rare earth elements such as: Dy, Ho, Tn and others. [6]. The spectra of these types of lamps shown in Fig.1d.

High pressure sodium lamps (HPSL) is the most efficient light sources. The efficiency of these lamps in PAR reaches 27%, which is 1,4-2 times more than fluorescent lamps, low pressure in 2,2-2,5 times more than for various high-pressure lamp type DRLF and xenon lamps and 7-8 times the efficiency of incandescent lamps. Lamps are very reliable (average life of more than 12000 hours) with high stability. Sodium lamps emit mainly in orange and yellow spectrum. There is a lack in the blue and red component of radiation and this is the main drawback of these lamps. The HPSL spectrum emission shown in Fig.1b.

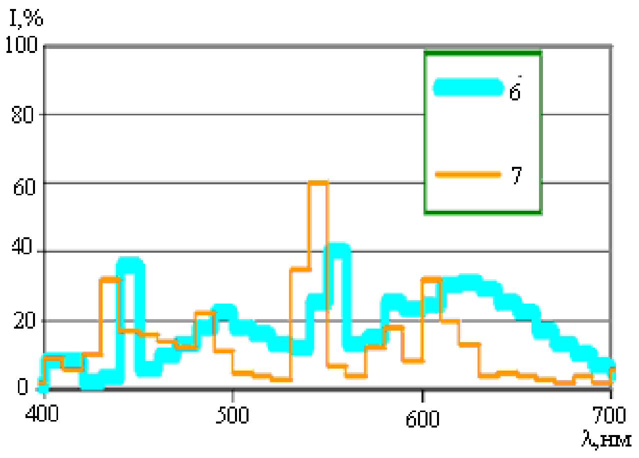
a)



b)



c)



d)

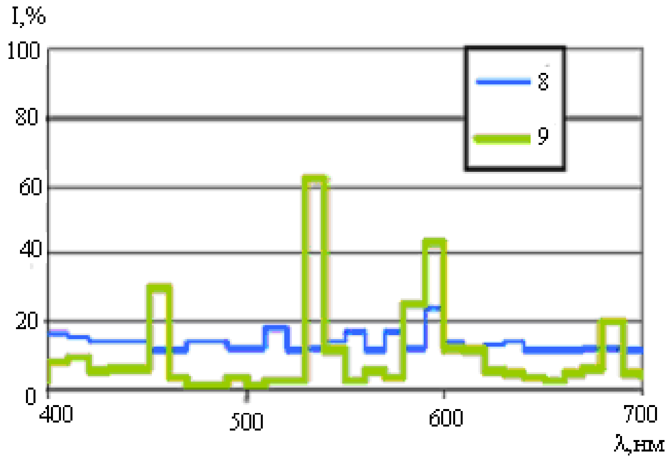


Fig.1. The spectrum emission of a) 1-incandencent lamps, 2-daily; b) discharge lamps, 3-xenon lamps, 4-mercury lamps with phosphor coating on the bulb, 5-high pressure sodium lamp; c) fluorescent lamps: 6- "white" light, 7-"day" light; d) metal halide lamps with the addition of halogens: 8-Na, Sc, Th, 9-Na, Tl, In.

Lamps for plants will encourage more intensive development of the plant, the more radiative energy will be contained in the spectrum of the radiation to which the plant is most vulnerable. [7]

To select the reasonable lamps spectrum radiation requirements we need to know the impact of radiation on different parts of the spectrum of plant growth and development. As it has been shown [10,11] for cucumber photoculture it is better to have radiation in the range of 500-600nm and 600-700nm. The best results for industrial technology are when the spectral ratio provides Es: Eze: Ek = (15-20)%, (35-45)%, (40-45)%. Significantly different conclusions about the best spectra were obtained on tomato cenosis [8]. When radiation is in the 600-700nm the tomato cenosis will be the highest. We need the radiation in the range of 400-500 and 500-600nm in minor proportions for providing photomorphological processes in plants. Requirements for better spectral characteristics of tomato photoculture looks like this: Es: Eze: Ek = (10-20)%, (15-20)%, (60-75)% [8].

The aim of this work is a comprehensive approach to the selection of high-intensity light sources for irradiation of tomato, cucumber and sprouts. We also need to install lighting characteristics dependent on structural parameters, namely the dependence of the energy of light flux and lamps power density light efficiency for the successful application of such lamps. Since the establishment of the theoretical dependency it is very difficult, the most realistic way to solve this problem remains experimental study of these characteristics.

Basic materials researchs. The basis for the plant photoculture LS choosing is on the principle of different set of characteristics comparing. The phyto activity radiation is taken for different LS that allows you to assess the relative efficiency of light emission in relation to a reference under the same illumination. [13]

In connection with the great importance of the qualitative characteristics of light for plant the requirements for light efficiency and durability of the artificial light sources are recently increased.

The main characteristics of various types high pressure sodium lamps are shown in Table 1.

Table 1 – The main characteristics of the various types high pressure sodium lamps.

Lamp type	Throttle type	Il, A	Ul, B	Pl, Wt	The spectral distribution			Φe, Wt	Efficiency, η %
					S_1	S_2	S_3		

DNaT-	1DBI-	4,3	130	415	0,10	0,44	0,46	124	29
400	400DNa	4,5	125	420	0,1	0,4	0,4	127	30
LUCALO	T/2200-	4,7	110	410	0	3	7	121	29
X	N-	5,1	95	380	0,1	0,5	0,3	102	27
SON-T	009UHL	4,9	98	340	0	6	4	100	29
HOC-1	1	5			0,1	0,5	0,4		
HOC-2			125	410	0	0	0	109	26
OSRAM-		4,5	105	385	0,0	0,5	0,4	102	27
NaVT		4,7			9	1	0		
SON		5							
					0,0	0,5	0,4		
					8	0	2		
					0,1	0,5	0,3		
					0	5	5		
HPI	BHL	3,55	130	380	0,30	0,58	0,12	92	25
SON-H	400L 11	3,3	145	345	0,10	0,45	0,45	89	26

Luminous efficiency (η) while lamp P_1 increases, and for sodium - mercury lamps at P_1 (25-60 Wt / cm) (η) is higher and it is 29±2%. So for plants photoculture at P1 > 58÷60 Wt / cm high pressure sodium lamp type DNaT-400, LUCALOX, SON-T, HOC-2 are more efficient.

PAR efficiency ($\eta_{ФАР}$) was counted as:

$$\eta_{ФАР}=\frac{F}{P} \qquad (1),$$

where F- the radiation flux in PAR,
P- lamp power.

According to [4]

$$F=\frac{Ф_{Л}(S_{\Delta\lambda1}+S_{\Delta\lambda2}+S_{\Delta\lambda3})}{683(0{,}02S_{\Delta\lambda1}+S_{\Delta\lambda2}+0{,}015S_{\Delta\lambda3})} \qquad (2),$$

where $S_{\Delta\lambda i}$ - the relative energy radiation in the spectral range Δλi,%: $\Delta\lambda_1$400-500nm, $\Delta\lambda_2$500-600nm, $\Delta\lambda_3$600-700nm,

683- light radiation efficiency, lm/Wt,

From (1) i (2) we will get:

$$\eta_{PAR} = \frac{\Phi}{P} \cdot \frac{1}{683(0{,}02S_{\Delta\lambda 1} + S_{\Delta\lambda 2} + 0{,}015S_{\Delta\lambda 3})} \quad (3),$$

Because $S_{\Delta\lambda 1}+S_{\Delta\lambda 2}+S_{\Delta\lambda 3}=1$,

and $\frac{\Phi л}{P}$ =H – luminous efficiency, than

$$\eta_{PAR} = \frac{H}{683(0{,}02S_{\Delta\lambda 1} + S_{\Delta\lambda 2} + 0{,}015S_{\Delta\lambda 3})} \quad (4)$$

According to the greenhouse and greenhouses plants process design standards for growing vegetables and seedlings [14], we can determine a number of lamps for cucumbers, tomatoes and seedlings, as follows:

$N=S\cdot W/W_l$, (5)

where S – floor area, м^2,

W – illumination power density, Wt / m^2 (for cucumbers, onions, green -70 Wt / m^2, for tomato seedlings W - 80Wt / m^2)

W_l – relative lamp power, Wt.

Conclusions. High-intensity sodium lamps are most suitable for growing cucumbers, tomatoes and seedlings in greenhouses conditions. With specific power P1 > 58÷60 Wt/sm luminous efficiency of these lamps is 29% and therefore, in our view, they should be recommended for wide use in greenhouses.

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