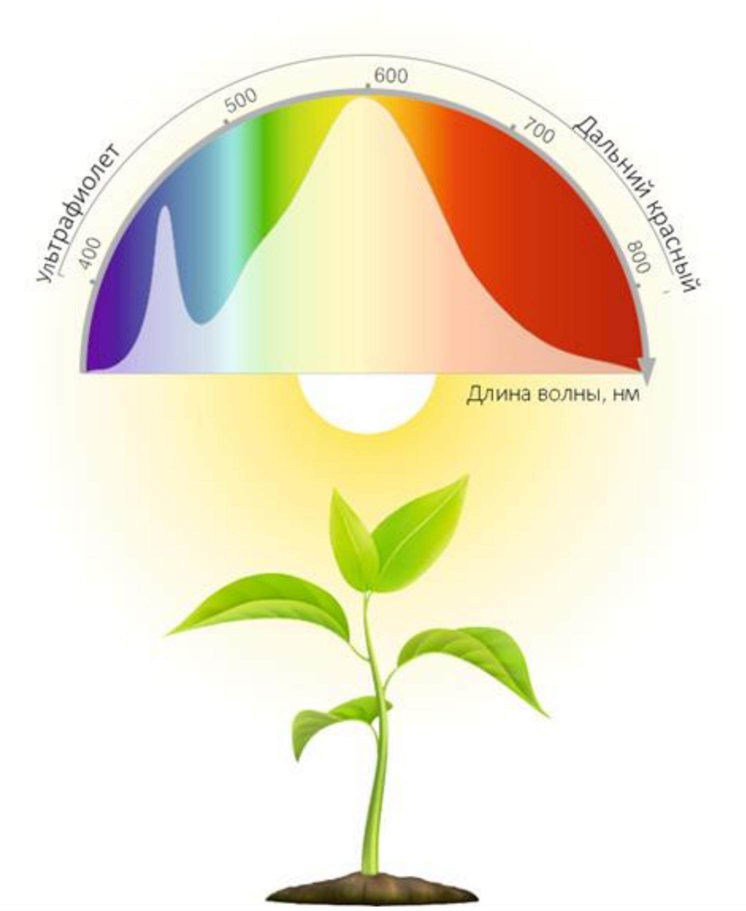
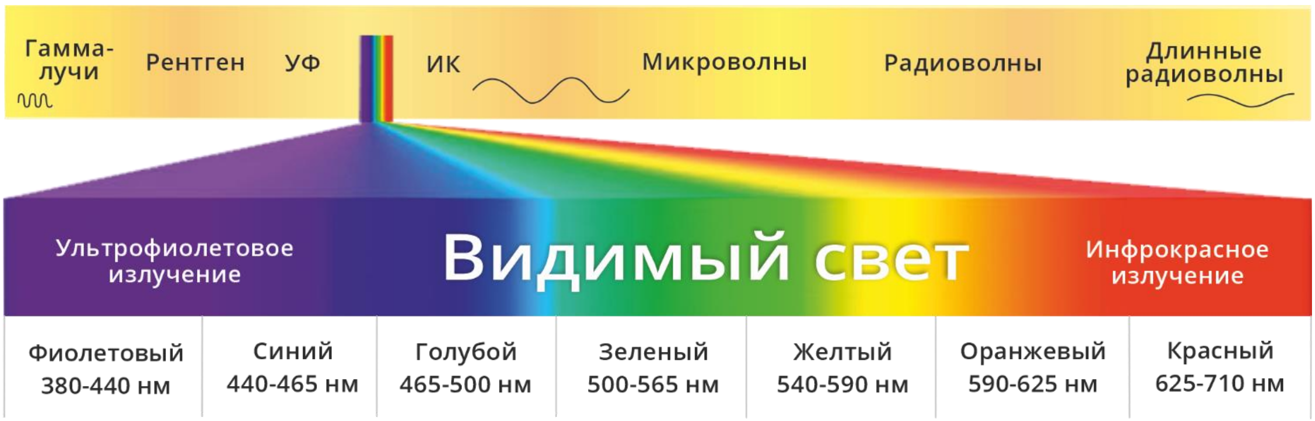
ARTIFICIAL LIGHTING OF PLANTS IN CULTIVATION FACILITIES OF PROTECTED SOIL



Minsk 2022

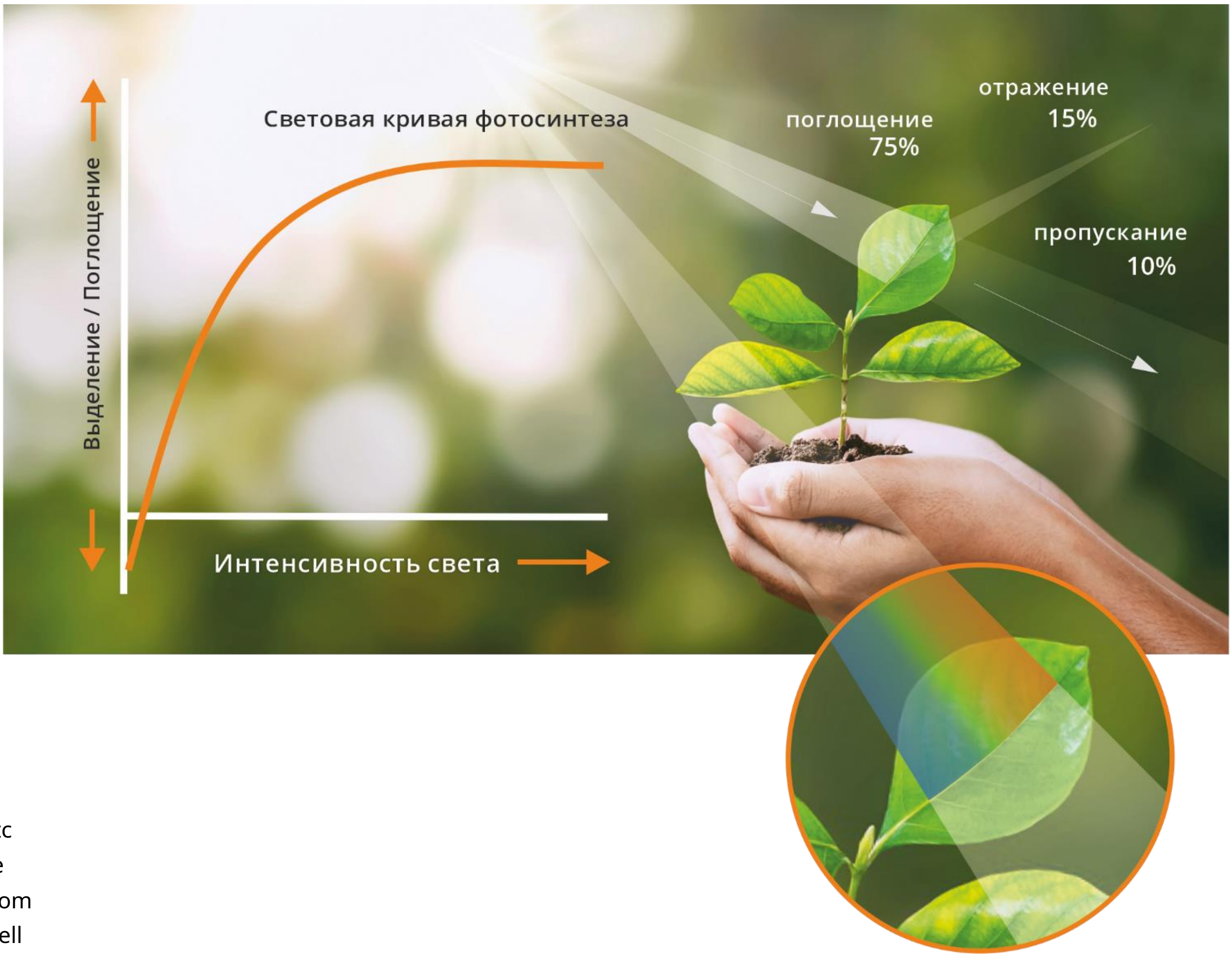
Sunlight and plants

Sunlight can be considered as part of the global electromagnetic radiation, including: radio and sound waves, long-wave infrared (IR, 700 - 3000 nm); visible (PAR, 380 - 710 nm), short-wave ultraviolet (UV, 200 - 380 nm) and X-ray radiation. Visible radiation is electromagnetic waves perceived by the human eye. The sensitivity of the human eye to electromagnetic radiation depends on the wavelength of the radiation, with the maximum sensitivity at 555 nm. Since the sensitivity drops to zero gradually with distance from the maximum point, it is impossible to indicate the exact boundaries of the spectral range of visible radiation. Usually, the section 380 - 400 nm is taken as a short-wave boundary, and in as a long-wave - 760 - 780 nm. Electromagnetic radiation with such wavelengths is also called visible light, or simply light (in the narrow sense of the word). When a white beam is decomposed in a prism, a spectrum is formed in which radiation of different wavelengths is refracted at different angles. The colors included in the spectrum, that is, those colors that can be obtained using light of one wavelength (more precisely, with a very narrow range of wavelengths), are called spectral colors. The indicated boundaries of the ranges are conditional, but in reality the colors smoothly transition into each other, and the location of the boundaries between them visible to the observer depends to a large extent on the observation conditions.



The flux of solar radiation through a unit surface is called energy irradiance (radiation intensity) and in the SI system is measured in W / m^2, and the total radiation (irradiation dose) - in J / m^2. In international practice, the concept of photosynthetic photon irradiance is often used, expressed in terms of photon flux density (PPFD - Photosynthetic Photon Flux Density) - the number of photons passing through a unit surface area per unit time. Since the number of photons is measured by large numbers, it is conventionally accepted to use the Avogadro number (6.022 x 10^{23}mole^{-one}). Thus, photon irradiance is measured in derived quantities: μmol/m^2, and the radiation dose is mol/m^2. The daily dose of radiation in international practice is called DLI (Daily Light Integral).

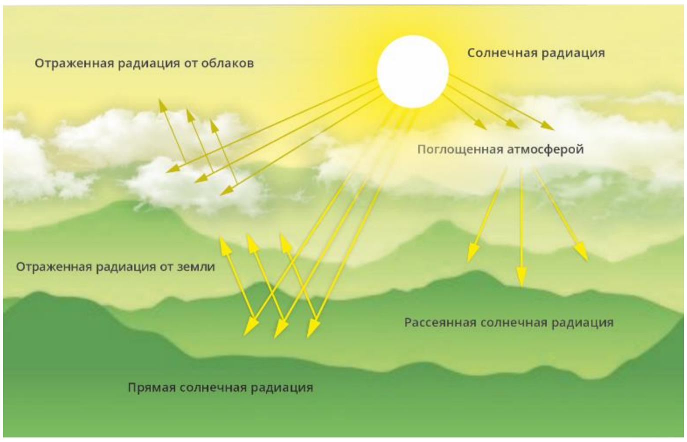
In the practice of greenhouse vegetable growing, such a concept is also used, as illumination. Illumination is a value equal to the ratio of the luminous flux, expressed in lumens (lm), falling on the surface, to its area. Illuminance is measured in lux (lux), 1 lux = 1 lm/m^2. A significant disadvantage of using the unit of measurement of illumination "lux" when determining the intensity of light under conditions of light culture is the low sensitivity of devices to the blue and red ranges of the spectrum, the presence of which in the total light flux is necessary for the normal growth and development of plants. At the same time, green light, which is of lesser physiological significance for plants than blue and red, are presented in the light system of units as the most important. Thus, measurements in lux "underestimate" the proportion of energy emitted in the "blue" and "red" regions of the spectrum.



etc
se
from
well
Active radiation (PAR) can be approximately calculated using the formula:

Q \u003d 0.43 * S + 0.57 * D,

where Q is the total volume of PAR; S is the total direct radiation; D is the total scattered radiation.



For a generalized assessment of the total PAR, a practical approach can be applied:

total PAR ≈ 50% of solar radiation.

About 75% of the PAR is captured by the leaves of the plant about 15% is reflected and about 10% passes through the leaves. This distribution of light energy does not change at different hours of the day. Energy is converted during biochemical processes or released into the surrounding air. **No more5% of solar energy is used for photosynthesis.** Intensive The rate of photosynthesis strongly depends on the irradiance of the phytocenosis with photosynthetic active radiation (photosynthetic irradiance). This dependence is expressed by a logarithmic curve, called the light curve of photosynthesis.

The photosynthetic apparatus of plants is adapted capable of using low irradiance (in most plants, photosynthesis begins already at an irradiance of 5 W/m$_2$). Total daylight illumination at noon on a summer sunny day reaches about 450 W/m on the Earth's surface.$_2$PAR or 2000 μmol/m$_2$PAR (about 100,000 lux or more).

There are three characteristic sections of the photosynthesis curve:

01 Rectilinear section to the level of irradiation 100 ... 150 W/m$_2$or 500 ... 750 μmol/m$_2$• with PAR (20000 ... 30000 lx). In this area, the rate of photosynthesis increases in proportion to the increase in irradiance.

02 Curvilinear section up to the level of irradiation 250 ... 300 W/m^2 or 1250 ... 1500 μmol/m^2• with PAR (50000 ... 60000 lx). In this region, the rate of photosynthesis slows down, but continues to increase, although not in proportion to the increase in irradiance.

03 Straight section. In this area, far

The slightest increase in irradiance does not cause a change in the rate of photosynthesis. The latter state is called the state of light saturation. In plants of the temperate zone, light saturation occurs at an irradiance of 100...200 W/m^2 or 500...1000 μmol/m^2• with PAR (20000...40000 lx).

The irradiance at which the intensity of photosynthesis is equal to the intensity of respiration is called the light compensation point.

About 75% of the light is absorbed by plants. The highest absorption level is observed in the blue-violet region, the lowest - in the green region of the spectrum. The level of light absorption in the spectral ranges in the first approximation is estimated approximately as follows:

"blue" area −**B**(400 - 500 nm) "green"	≈ 90%
area −**G**(500 - 600 nm) "red" area −**R**(600	≈ 60%
- 700 nm)	≈ 80%

Light, as a physical factor of the external environment, plays a key role in the control and regulation of intracellular processes of the plant organism throughout its life, performing two main functions in the cell - energy and information. The first is realized in the process of photosynthesis, during which the energy of light is transformed into the chemical energy of the bonds of organic compounds. The second function of light is to launch various regulatory reactions, while light quanta act as an information carrier. In the case of regulatory reactions, light is absorbed by specialized photoreceptors, the absorption of light by which initiates signal cascades in the cell that modulate the activity of enzymes, gene expression, and various physiological parameters of the cell.

In higher plants, non-

how many complex photoreceptor protein systems for the perception of light of different spectral composition: red/far red (phytochromes), blue/UV-A (cryptochromes, phototropins, ZTL/FKF1/LKP2) and UV-B light (UVR8). Changes in the light regime of plant growth cause extensive reprogramming of the nature of gene expression in plants due to the transmission of signals from photoreceptor through complex networks of second messengers to various effective systems. Due to this, photoreceptor systems have a great influence on the processes associated with the growth and development of plants, as well as on the formation of their biologically useful properties. With the help of changes in the spectral composition of irradiation installations used in greenhouses, it is possible to vary the useful characteristics of plant tissues, which are important both for ensuring intensive growth and development of plants in a greenhouse and improving the quality of future plant products (due to an increase in the content of nutrients). substances or compounds with organoleptic and pharmacological properties).

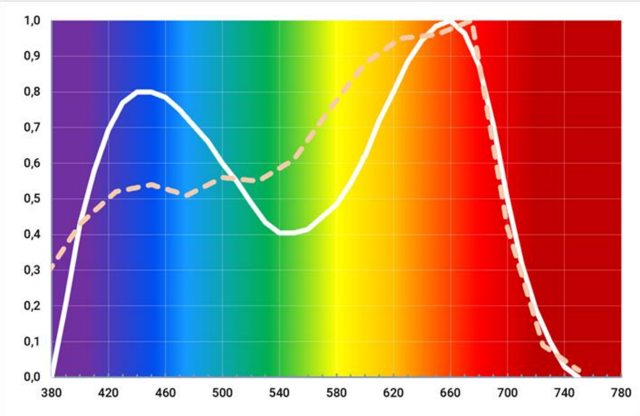
Photosynthesis proceeds most rapidly in red and blue-violet rays, because they are better absorbed by the plant leaf pigments. The dependence of the efficiency of the chemical (biological) action of light on its wavelength is called the action spectrum, therefore, the dependence of the intensity of photosynthesis on the wavelength of the light is called the action spectrum of photosynthesis. The maximum intensity of photosynthesis is observed under illumination with red rays. The intensity and spectral composition of light affect the chemical composition of photosynthesis products. At high illumination, more carbohydrates are formed, at low illumination - organic acids. Red light stimulates the formation of carbohydrates and cell elongation, and inhibits the formation of lateral roots. Blue light stimulates respiration, the formation of amino acids and proteins, stimulates cell division, but inhibits their stretching.

At present, models of spec-

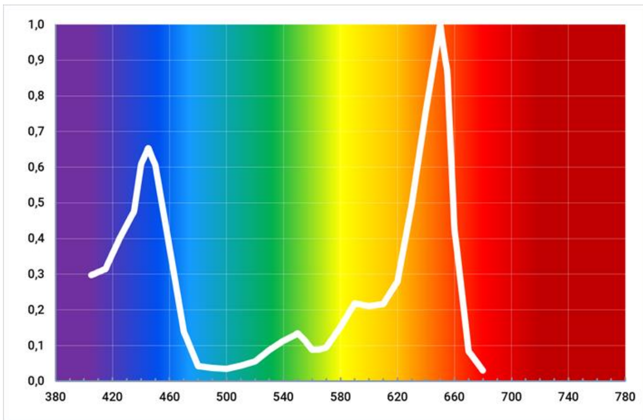
action lines: leaf photosynthesis, chlorophyll synthesis, photomorphogenesis, phototropism. In the European Union, from March 1, 2018, the standard DIN5031-10-2018 “Physics of optical radiation and lighting engineering. Photobiologically active radiation. Dimensions, conventions and spectra of action.

Experimental dependencies indicate a special role of the "violet-blue" and "red" regions of the spectrum in ensuring photosynthesis and, consequently, the vital activity of the plant as a whole. However, this conclusion has only a fundamental qualitative character. Attempts to build on the function of the spectral photosynthetic efficiency of optical radiation for plants obtained experimentally or by calculation turned out to be unsuccessful. Today it can be argued that the direct

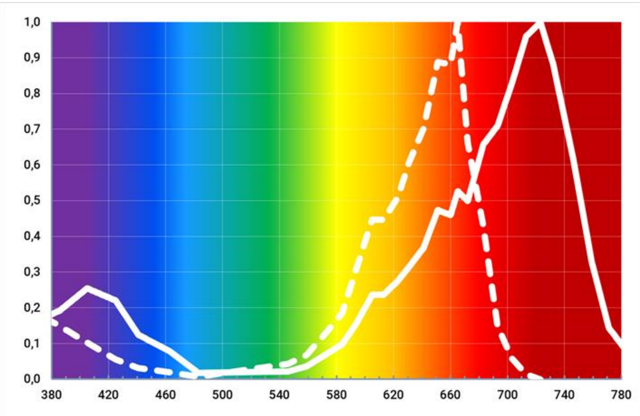
In most cases, there is no correlation between the intensity, more precisely, the quantitative measure of photosynthesis, and the accumulation of the total and even more useful biomass (yield). Studies show that the "two-humped" function photosynthetic efficiency in the transition from a leaf to a plant and, then, to a plant community (phytocenosis) more and more approaches the U-shaped, i.e. equal to energy ("solar").



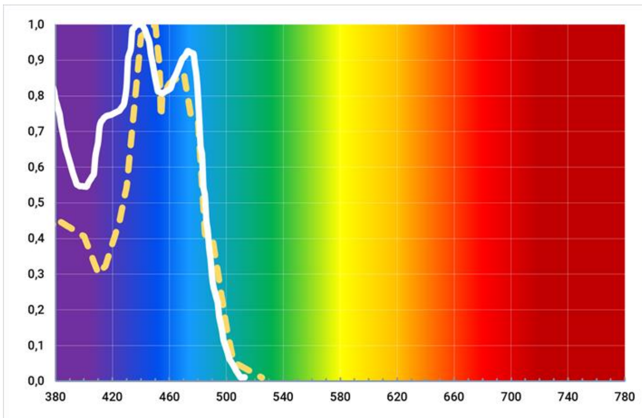
Action spectrum of photosynthesis



Action spectrum of chlorophyll synthesis



Action spectrum of photomorphogenesis



Action spectrum of phototropism

In addition, the growth and development of a plant, as a complex organism, is determined not only by photoenergetic processes (photosynthesis), but also by photoregulatory (the most important - photomorphogenesis), regulating the metabolism (metabolism) of plants. The existing differences in the response to the spectral composition of the acting optical radiation are imposed by the specific features of plants, as well as other important environmental parameters (temperature, humidity, carbon dioxide content, etc.).

In view of the foregoing, the only correct
A special photobiological experiment in a controlled environment is a special method for determining the spectral characteristics of optical radiation that provides the best beneficial effect for specific types of crops.

Light affects the work of stomatal cells and is etsya main factor regulating transpiration: less than 5% of the absorbed light is spent on photosynthesis, the rest of the light is converted into thermal energy, which is spent on the evaporation of water.

Light also affects the absorption of nutrients: in the dark it slows down and gradually stops and intensifies in the light, especially with an increase in the transpiration flow. Reducing the daylight period inhibits the absorption of nitrogen and the synthesis of amino acids. Also, with a lack of light, the root system develops poorly. The composition of photosynthesis products is also affected by the rapid transition from darkness to light and vice versa. First, after turning on the high-intensity light, non-carbohydrate products are predominantly formed, and only after some time - carbohydrates. After turning off the light, on the contrary, the leaves do not immediately lose their ability to photosynthesis. First, the synthesis of carbohydrates is inhibited, and only then organic acids and amino acids.

Ideas about the impact on life

The plant characteristics of individual PAR ranges and adjacent UV and IR regions of optical radiation undergo some changes as experimental data are accumulated. In particular, ideas about the signal or the regulatory role of the optical radiation ranges 300–400 nm and 700–800 nm. Without directly participating in photosynthesis, they significantly affect it and affect the growth and development of plants, forming, in particular, their adaptive responses.

The effect of light on plants

UV-C	200 - 280 nm	Radiation is detrimental to the life of plants. Virtually absent in sunlight near the Earth's surface. Radiation causes photolysis of water, forming free active radicals and hydrogen peroxide, and the latter, in turn, oxidize and destroy organic molecules - living cells begin to die
UV-B	280 - 320 nm	Radiation can increase cold hardiness in plants
	320 - 350 nm	Radiation at low doses can enhance plant pigmentation and lead to accelerated growth and increased plant productivity.
UV-A	350 - 400 nm	Radiation delays the "stretching" of plants and stimulates the synthesis of certain vitamins, increases the synthesis of alkaloids and essential oils, which can cause reddening of lettuce leaves.
Blue	400 - 500 nm	Radiation is directly involved in photosynthesis, stimulates the formation of proteins and regulates the rate of plant development. Blue light, forming a significant amount of growth inhibitors in the leaves, inhibits the growth of shoots and leads to the formation of low-growing plants, stimulating the flowering of short-day plants, and slows down the development of long-day plants.
Green	500 - 600 nm	According to classical concepts, radiation is not absolutely necessary to ensure plant photosynthesis, but due to its high penetrating power it is useful for ensuring photosynthesis of optically dense leaves and dense plant crops. In recent years, in practical photobiological studies, more and more data have appeared on the significant role of this spectral range when growing plants using light culture technology.
Red	600 - 700 nm	Radiation is of the greatest importance in the life of plants. It, of course, must be included in the total radiation to ensure efficient photosynthesis and achieve high productivity. However, quasi-monochromatic red light can lead to abnormal growth and development, and in some cases even death of some plant species.
Further red	700 - 800 nm	Radiation has a pronounced regulatory effect. It must be included in the composition of the radiation in an amount of several percent.
Infra-red	> 800 nm	Radiation cannot initiate photochemical reactions. Infrared radiation of some wavelengths is absorbed by the water molecules contained in the plants and thus can raise the temperature of the plants

Amount of light and plants

Obtaining a good economically useful crop of vegetables and other crop products is possible with a harmonious balance of abiotic environment factors.

It is necessary to take into account not only the intensity of irradiation of plants, but the duration of the photoperiod, which will be used in a particular technological process. The product of the PAR intensity and the duration of the photoperiod is the plant irradiation dose, that is, the amount of energy coming to the plants in the PAR region. The same doses of irradiation of plants can be obtained at a low level of irradiation, corresponding to weak photosynthesis and a long photoperiod, and vice versa, at a high level of irradiation,

relevant intensive

photosynthesis and shortened photoperiod. Therefore, it is necessary to determine the intensity of irradiation and the duration of the photoperiod in a certain ratio in accordance with agricultural technology.

The maximum values of the efficiency factor of phytocenoses in terms of economically useful biomass of the main light crops of greenhouse vegetable growing are in the irradiation ranges:

- cucumber100-150 W/m_2
- tomatoes150-180 W/m_2

According to the developments of the Giproni-selprom (Russia), the following optimal standardized irradiance in the greenhouse is recommended: 40 W/m_2(180 – 200 $\mu mol/m_2$•c) PAR with a photoperiod of 14 hours when growing seedlings;
100 W/m_2(450 – 500 $\mu mol/m_2$• c) PAR with a photoperiod of 16 hours when growing plants for production.

In this case, the optimal daily amount
The irradiation effect (dose) will be:

➢ for seedlings:
560 Wh/m_2or 2.0 MJ/m_2or 9 – 10 mol/m_2
➢ for growing plants for products:
1600 Wh/m_2or 5.8 MJ/m_2or 26–29 mol/m_2.

Industry recommendations for tomatoes: ≈ 1.0 MJ/ m3 is needed per day to maintain the life of a tomato plant2or 5 mol/m_2. For the development of each hand, an additional 0.4 ... 0.85 MJ/m_2or 2 ... 4 mol/m_2. The amount of light required depends on the type of tomato (large-fruited, cluster, cocktail or cherry tomato), planting density and fruit load per 1 $m_2$area. At the same time, to create a reserve, young plants with one brush should receive up to 3 MJ / $m_2$or 15 mol/m_2in a day. Thus, during the formation of a tomato phytocenosis with 8–9 racemes on a stem, the need for PAR is approximately 8.5 MJ/m_2

or 40 mol/m_2.

The conceptual guideline for the design technological lighting of greenhouses are NTP 10-95 "Technological design standards for the technological design of greenhouses and greenhouse plants for growing vegetables and seedlings" (Russia):

“6.1.1. In seedling compartments (greenhouses) of vegetable greenhouses, the minimum total (natural + artificial) irradiance should be at least 25 W/m_2PAR (120 $\mu mol/m_2$ •With). Daily amount of PAR not less than 250 W x h/m_2PAR (0.9 MJ/m_2• days or 4.5 mol/m_2• days).

6.1.2. In vegetable greenhouses, the irradiance should be at least 70 W / m_2PAR (320 $\mu mol/m_2$•c), the daily amount of PAR for vegetable crops during the fruiting period is at least 900 W x h/m_2PAR (3.2 MJ/m_2• days or 15 mol/m_2• days).

6.1.3. When developing crop rotations, one should take into account the daily amount of natural PAR passing into the greenhouse. If the daily amount of PAR passing into the greenhouse is less than 0.9 of the minimum physiological criterion, it is recommended to provide for additional artificial irradiation.

6.1.4. When growing plants under conditions of artificial irradiation for seedlings and seedlings it is recommended to take an irradiance of 80 W/m_2(350 $\mu mol/m_2$•c), for vegetable crops 80 – 160 W/m_2PAR (350 - 700 $\mu mol/m_2$•With)".

The norms for the technological design of greenhouses and greenhouse complexes for growing vegetables and seedlings NTP 10-95 were developed by the State Research and Design Institute for the creation of storage facilities, processing of fruits and vegetables, greenhouses and artificial climate facilities "Giproniselprom" of the Ministry of Agriculture and Food (Russian Federation), approved by the Glavgosexpertiza under the Ministry of Construction of Russia N 24-3-1/5-122 dated 09/27/1995, the State Committee for Sanitary and Epidemiological Supervision of Russia N 11-13/806-115 dated 04/15/1996, the Main Directorate of the State Fire Service of the Ministry of Internal Affairs Russia N 20/2.2/1392 dated 07/19/1995, Republican Production and Scientific Association "Greenhouses of Russia" N 10 dated 04/04/1996.

Photoperiod, irradiation of agrophytocenosis, the spatial structure of the light field and the spectral composition of optical radiation are the main lighting parameters for growing plants in protected ground conditions.

Direct relationship between yield and intensity photosynthesis is not always observed. The highest intensity of photosynthesis is observed in plants of deserts and semi-deserts, and plants grow extremely slowly there. In the tropics, conditions for growth are favorable, but the intensity of photosynthesis is low. The average rate of photosynthesis under field conditions is 5 times less than the potential one, and under extreme conditions it often drops to zero. The way to increase the average sustainable intensity of photosynthesis is to create optimal microclimate conditions for plants.

Of great importance is the speed of formation vanes and final leaf area. If the plants form a small leaf surface, then the yield is low; if there are many leaves, then the lower leaves may not have enough light, and the intensity of photosynthesis will be at the level of compensation. To characterize the leaf area, the value of the leaf index is usually used. The leaf area index (LSI) is the ratio of the total surface area of all leaves to the soil area occupied by these plants. The optimal leaf area for sowing depends on the location on the stem. The more vertically the leaves are, the less the upper leaves shade the lower ones and the greater, perhaps, the leaf area index.

Typically, the ILI ranges from 2.0 to 3.7. One-however, in wheat it reaches 7. In sugar cane, as in other tropical cereals, it can theoretically reach 15. In plants with adjacent to the ground rosette of leaves, the maximum intensity of photosynthesis in the crop is achieved already at the ILP equal to 1.0 - 1.5. At the same time, plants with narrow leaves arranged more or less vertically and evenly on the shoot have a high intensity of photosynthesis with an ILI equal to 4...5, and in wheat - up to 8...10. High-yielding varieties of sugar beet have funnel-shaped rosettes of leaves raised above the ground, and low-yielding varieties are flattened on the ground.

An increase in leaf area is favorable for the crop only up to a certain limit. On average, up to 5 m is considered optimal for the temperate zone$_2$leaves per 1 m_2 arable land, for the humid tropics - 10 m_2. With its further increase, mutual shading of the leaves begins, the flow of light to the lower leaves worsens, which leads to a decrease in net productivity of photosynthesis. Too much increase in the leaf surface in agricultural sowing or planting can lead to a decrease in the economically useful yield, since the leaves will shade each other, and the more leaves, the more assimilants are spent on their formation.

The leaf index is one of the important indicators lei, which determine the amount of light absorbed by plants of a given population. The formation of an optimal leaf surface in sowing is the main method of yield management.

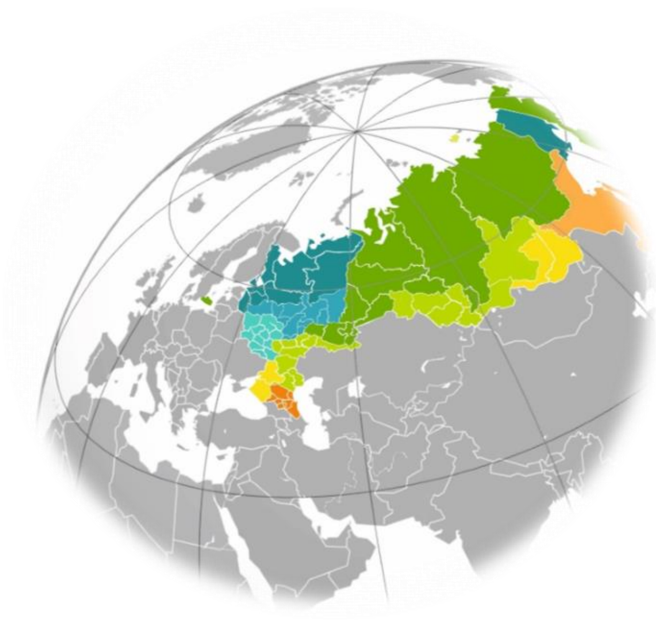
Another way to increase productivity is to increase The percentage of the use of photosynthetic active radiation. Under natural conditions, plants use 2–5% of the absorbed energy for photosynthesis, in artificial conditions - up to 10%.

Recommended Plant Irradiation Doses

plant variety	Daily exposure dose (DLI)		Irradiation	
	MJ/m_2	mol/m_2	W/m_2	μmol/m_2•With
micropropagation of plants	0.5 - 1.0	2.5 - 5.0	10 – 20	50 - 100
Microgreens, green crops, seedlings	1.0 - 2.0	5.0 - 10.0	20 - 40	100 - 200
Berry crops	2.0 - 4.0	10.0 - 20.0	40 - 80	200 - 400
Vegetable crops (tomato, cucumber, pepper)	4.0 - 8.0	20.0 - 40.0	80 - 120	400 - 600

In world practice, all types of cultivation The most important structures are created taking into account the maximum use of solar radiation. Solar radiation is the main climatic factor that determines the types and types of cultivation facilities in a given area, a set of crops by periods and terms of their cultivation. Solar radiation has a certain intensity, spectral composition and daily duration depending on the area of vegetable crops growing in cultivation facilities.

On the territory of Russia, there is mainly nom latitudinal distribution of total solar radiation: the sums decrease as we move from south to north. On the basis of many years of research, zoning of the territory of Russia was carried out according to the influx of natural PAR penetrating into greenhouses in the autumn-winter period. In accordance with the calculated monthly amounts of the total PAR in December-January (the most critical months of the year in terms of inflow solar radiation) Russia is conditionally divided into 7 light zones according to the increasing amount of PAR.



The value of photosynthetic irradiation of plants in a greenhouse consists of two components: natural and artificial PAR. In greenhouses located in the southern regions of the world, the contribution of the natural PAR component will be higher than for greenhouses located in the middle lane, and even more so in northern regions. Incorrectly selected light irradiation regimes can lead to a shortage of plant yield with a lack of artificial light, or to an unreasonable increase in the cost of plant production in case of its excess.

Light zones of Russia

I	Arkhangelsk region	Vologda region	Leningrad region.	110 - 220 cal/cm^2
	Magadan region	Novgorod region	Pskov region	5 – 10 MJ/m^2
	Republic of Karelia	Komi Republic		
II	Ivanovo region	Kirov region	Kostroma region	400 - 580 cal/cm^2
	Nizhny Novgorod region.	Perm region	Mari El Republic	15 - 25 MJ/m^2
	The Republic of Mordovia	Tver region	Udmurt republic	
	Chuvash Republic	Yaroslavl region		
III	Belgorod region	Bryansk region	Vladimir region	610-970 cal/cm^2
	Voronezh region	Kaliningrad region	Kaluga region	25 - 40 MJ/m^2
	Krasnoyarsk region	Kurgan region	Kursk region	
	Lipetsk region	Moscow region	Oryol region	
	Republic of Bashkortostan	Republic of Sakha (Yakutia)	Republic of Tatarstan	
	Republic of Khakassia	Ryazan region	Sverdlovsk region.	
	Smolensk region	Tambov region	Tomsk region	
IV	Altai region	Astrakhan region	Volgograd region	1000 - 1380 cal/cm^2
	Irkutsk region	Kamchatka region	Kemerovo region.	40 - 60 MJ/m^2
	Novosibirsk region	Omsk region	Orenburg region	
	Penza region	Altai Republic	Republic of Kalmykia	
	Republic of Tuva	Samara region	Saratov region	
	Ulyanovsk region			
V	Krasnodar Territory (except for the Black Sea coast) Republic of Adygea Republic of			1450 - 1670 cal/cm^2
	Buryatia	Rostov region	Chita region	60 - 70 MJ/m^2
VI	Krasnodar Territory (Black Sea coast) Kabardino-		The Republic of Dagestan	1770 - 2080 cal/cm^2
	Balkarian Republic		The Republic of Ingushetia	75 - 85 MJ/m^2
	Karachay-Cherkess Republic Republic of		Stavropol region	
	North Ossetia-Alania		Chechen Republic	
VII	Amur region	Primorsky Krai	Sakhalin region	2370 - 3450 cal/cm^2
	Khabarovsk region			100 - 145 MJ/m^2

Approximately solar radiation and sum of PAR under average cloudiness conditions at 60$_0$With. sh.

Energy for the period		Unit rev.	Month											
			I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
month	Total	MJ/m$_2$	37	94	261	374	590	634	596	432	237	104	36	eighteen
	PAR	MJ/m$_2$	17	42	117	168	266	285	268	194	107	47	16	eight
		mol/m$_2$	75	190	529	757	1195	1284	1207	875	480	211	73	36
day	Total	MJ/m$_2$	1.2	3.4	8.4	12.5	19.0	21.1	19.2	13.9	7.9	3.4	1.2	0.6
	PAR	MJ/m$_2$	0.5	1.5	3.8	5.6	8.6	9.5	8.7	6.3	3.6	1.5	0.5	0.3
		mol/m$_2$	2	7	17	25	39	43	39	28	16	7	2	one

Approximately solar radiation and sum of PAR under average cloudiness conditions at 55$_0$With. sh.

Energy for the period		Unit rev.	Month											
			I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
month	Total	MJ/m$_2$	80	164	342	439	599	642	613	507	308	145	74	51
	PAR	MJ/m$_2$	36	74	154	198	270	289	276	228	139	65	33	23
		mol/m$_2$	162	332	693	889	1213	1300	1241	1027	624	294	150	103
day	Total	MJ/m$_2$	2.6	5.9	11.0	14.6	19.3	21.4	19.8	16.4	10.3	4.7	2.5	1.7
	PAR	MJ/m$_2$	1.2	2.6	5.0	6.6	8.7	9.6	8.9	7.4	4.6	2.1	1.1	0.7
		mol/m$_2$	5	12	22	thirty	39	43	40	33	21	9	5	3

Approximately solar radiation and the sum of the PAR under average cloudiness conditions at 47$_0$With. sh.

Energy for the period		Unit rev.	Month											
			I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
month	Total	MJ/m$_2$	126	166	303	460	607	692	685	598	440	281	117	92
	PAR	MJ/m$_2$	57	75	136	207	273	311	308	269	198	126	53	41
		mol/m$_2$	255	336	614	932	1229	1401	1387	1211	891	569	237	186
day	Total	MJ/m$_2$	4.1	5.9	9.8	15.3	19.6	23.1	22.1	19.3	14.7	9.1	3.9	3.0
	PAR	MJ/m$_2$	1.8	2.7	4.4	6.9	8.8	10.4	9.9	8.7	6.6	4.1	1.8	1.3
		mol/m$_2$	eight	12	twenty	31	40	47	45	39	thirty	eighteen	eight	6

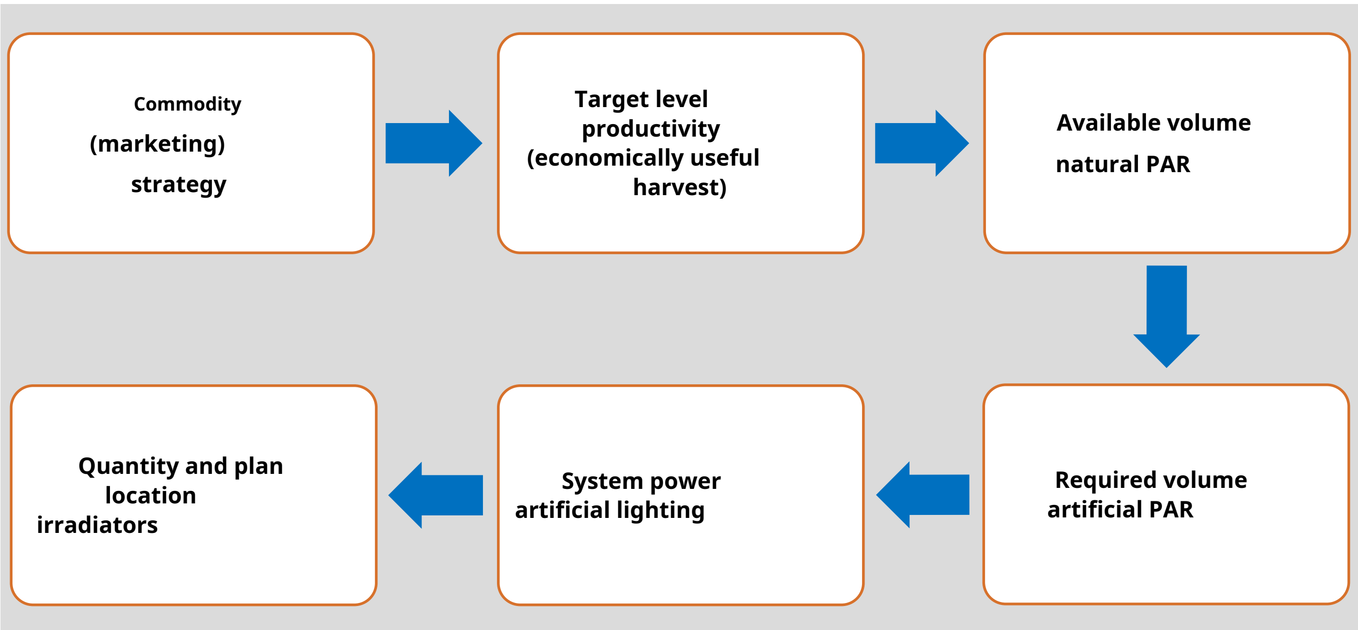
Approximately solar radiation and sum of PAR under average cloudiness conditions at 43$_0$With. sh.

Energy for the period		Unit rev.	Month											
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
month	Total	MJ/m$_2$	144	188	321	491	678	719	718	629	445	309	162	124
	PAR	MJ/m$_2$	65	85	144	221	305	324	323	283	200	139	73	56
		mol/m$_2$	292	381	650	994	1373	1456	1454	1274	901	626	328	251
day	Total	MJ/m$_2$	4.6	6.7	10.4	16.4	21.9	24.0	23.2	20.3	14.8	10.0	5.4	4.0
	PAR	MJ/m$_2$	2.1	3.0	4.7	7.4	9.8	10.8	10.4	9.1	6.7	4.5	2.4	1.8
		mol/m$_2$	9	fourteen	21	33	44	48	47	41	thirty	twenty	eleven	eight

Recommended power density of greenhouse irradiators

Calculation of the optimal power of the irradiator The installation of a greenhouse is an important engineering challenge. Accurate calculations based on fundamental and applied sciences are still difficult. In practice, empirical data obtained during the experience of using artificial lighting or on the basis of industrial experiments in greenhouses are used. The plan for the production of an economically useful crop is the basis for calculating the need for PAR. This is possible when using empirical data on the energy intensity of an economically useful product. The plan for the production of marketable products can be focused on summer or winter cultivation, and also provide for year round production. Based on the geographical location of the greenhouse, meteorological observations in the given region and the light transmission coefficient of the greenhouse, the dose of irradiation of agrophytocenosis in the greenhouse with natural (solar) PAR during the calendar year is calculated.

The calculation of the required volume of artificial PAR is performed based on the difference between the required level and the resulting volume of natural (solar) PAR. The maximum duration of the irradiation installation during the day is determined by the possible length of day and night for the grown plants (short or long day plants)



Growing plants in glass or film greenhouses

<table>
<tr><td colspan="4" rowspan="2">Options</td><td colspan="3">Power level</td></tr>
<tr><td>reduced</td><td>average</td><td>elevated</td></tr>
<tr><td colspan="4">Step (spacing)**S**between lines of lamps, m</td><td>2.0</td><td>1.5</td><td>1.0</td></tr>
<tr><td colspan="4">Specific power consumption, W/m_2</td><td>100</td><td>130</td><td>200</td></tr>
<tr><td colspan="4">Horizontal energy irradiance, W/m_2</td><td>45</td><td>60</td><td>90</td></tr>
<tr><td colspan="4">Horizontal photon irradiance, μmol/m_2*With</td><td>225</td><td>300</td><td>450</td></tr>
<tr><td rowspan="10">Daily light integral (DLL)

Radiation dose</td><td rowspan="10">Photoperiod, hours</td><td rowspan="2">12</td><td>MJ/m_2</td><td>1.9</td><td>2.6</td><td>3.9</td></tr>
<tr><td>mol/m_2</td><td>9.7</td><td>13.0</td><td>19.4</td></tr>
<tr><td rowspan="2">fourteen</td><td>MJ/m_2</td><td>2.3</td><td>3.0</td><td>4.5</td></tr>
<tr><td>mol/m_2</td><td>11.3</td><td>15.1</td><td>22.7</td></tr>
<tr><td rowspan="2">16</td><td>MJ/m_2</td><td>2.6</td><td>3.5</td><td>5.2</td></tr>
<tr><td>mol/m_2</td><td>13.0</td><td>17.3</td><td>25.9</td></tr>
<tr><td rowspan="2">eighteen</td><td>MJ/m_2</td><td>2.9</td><td>3.9</td><td>5.8</td></tr>
<tr><td>mol/m_2</td><td>14.6</td><td>19.4</td><td>29.2</td></tr>
<tr><td rowspan="2">twenty</td><td>MJ/m_2</td><td>3.2</td><td>4.3</td><td>6.5</td></tr>
<tr><td>mol/m_2</td><td>16.2</td><td>21.7</td><td>32.4</td></tr>
</table>

Growing plants in closed cultivation facilities without sunlight

<table>
<tr><td colspan="2" rowspan="2">**Options**</td><td colspan="3">Power level</td></tr>
<tr><td>reduced</td><td>average</td><td>elevated</td></tr>
<tr><td colspan="2">Step (spacing)**S**between lines of lamps, m</td><td>1.0</td><td>0.65</td><td>0.5</td></tr>
<tr><td colspan="2">Specific power consumption, W/m_2</td><td>200</td><td>300</td><td>400</td></tr>
<tr><td rowspan="2">Daily light integral (DLI)
Radiation dose</td><td>MJ/m_2</td><td>3.4</td><td>5.2</td><td>7.0</td></tr>
<tr><td>mol/m_2</td><td>17</td><td>26</td><td>35</td></tr>
<tr><td colspan="2">Photoperiod, hours</td><td>12</td><td>12</td><td>12</td></tr>
<tr><td colspan="2">Horizontal energy irradiance, W/m_2</td><td>80</td><td>120</td><td>140</td></tr>
<tr><td colspan="2">Horizontal photon irradiance, μmol/m_2*With</td><td>400</td><td>600</td><td>800</td></tr>
</table>

Lamp FLORA LED

Application area

The FLORA LED luminaire is designed to create energy-efficient artificial lighting in greenhouse cultivation facilities (greenhouses, phytotrons, etc.):

- in addition to natural daylight;
- to control the light period (photoperiodic lighting);
- for complete replacement of daylight with artificial lighting (cultivation without daylight).

Design

Framemade of high quality aluminium.

Protective glassmade from stabilized ultraviolet optical polycarbonate.

LEDs– high-performance LEDs:NICHIA (Japan) and Seoul Semiconductor (South Korea).

Source of power– produced by the companyMean Well" (Taiwan) AC - DC.

Side covers Made from durable polymer material.

Fasteningallows you to install lamps in a warm face on: trays, cables, busbars.

Specifications

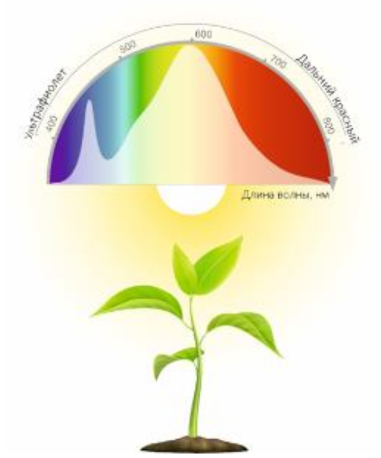
Light distribution class	P	Energy efficiency class	A+
Luminous intensity curve type	D	Protection class	I
Supply voltage, V	230	Degree of protection	IP65
Supply current frequency, Hz	fifty	Type of climatic modification	UHL4
Power factor, not less than	0.95	Operating temperature range, °C	- 1 ... + 40

Designation lamps	Power consumption, Tue	Flow radiation, Tue	Flow photons, μmol/s	Dimensions, mm	The weight, kg	Price without VAT, Euro
A series of lamps on LEDs NICHIA (Japan)						
FLORA LED 50 DSP08-1x50-004 UHL4	55	22	105	400x134x80	1.2	
FLORA LED 100 DSP08-2x50-004 UHL4	110	44	210	700x134x80	1.9	
FLORA LED 150 DSP08-3x50-004 UHL4	160	66	315	1000x134x80	2.3	
FLORA LED 200 DSP08-4x50-004 UHL4	215	88	420	1300x134x80	2.7	
FLORA LED 250 DSP08-5x50-004 UHL4	260	110	525	1600x134x80	3.2	
A series of lamps on LEDs Seoul Semiconductor (South Korea)						
FLORA LED 60/0.4 DSP08-1x60-004 UHL4	65	thirty	150	400x134x80	1.2	
FLORA LED 120/0.7 DSP08-2x60-004 UHL4	130	60	300	700x134x80	1.9	
FLORA LED 180/1.0 DSP08-3x60-004 UHL4	195	90	450	1000x134x80	2.3	
FLORA LED 240/1.3 DSP08-4x60-004 UHL4	260	120	600	1300x134x80	2.7	
FLORA LED 300/1.6 DSP08-5x60-004 UHL4	330	150	750	1600x134x80	4.0	

The FLORA LED lamp is a light source in the wavelength range of 380-780 nm, providing the course of the whole variety of photobiological processes inherent in plant organisms.

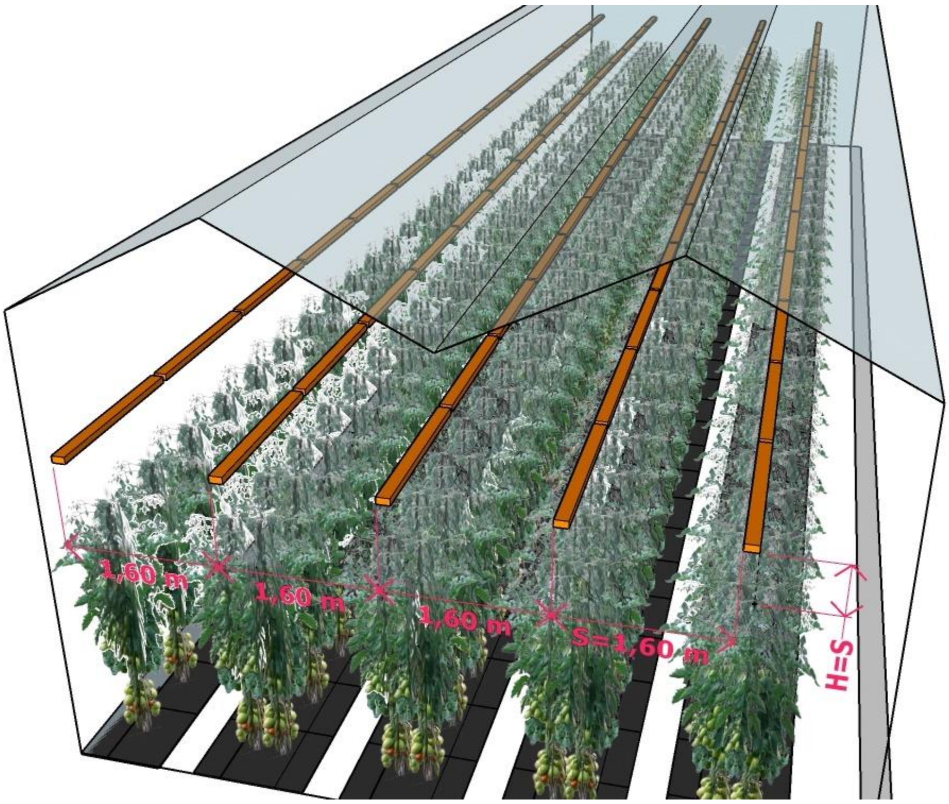
The nominal life of the luminaire is 10 years with reliability indicators $L_{90}F_{ten}$≥60000 hours according to GOST R 56230-2014 (Russia) and IEC/PAS 62717:2011 (EU).

Warranty period of operation - 36 months.



Installation Recommendations

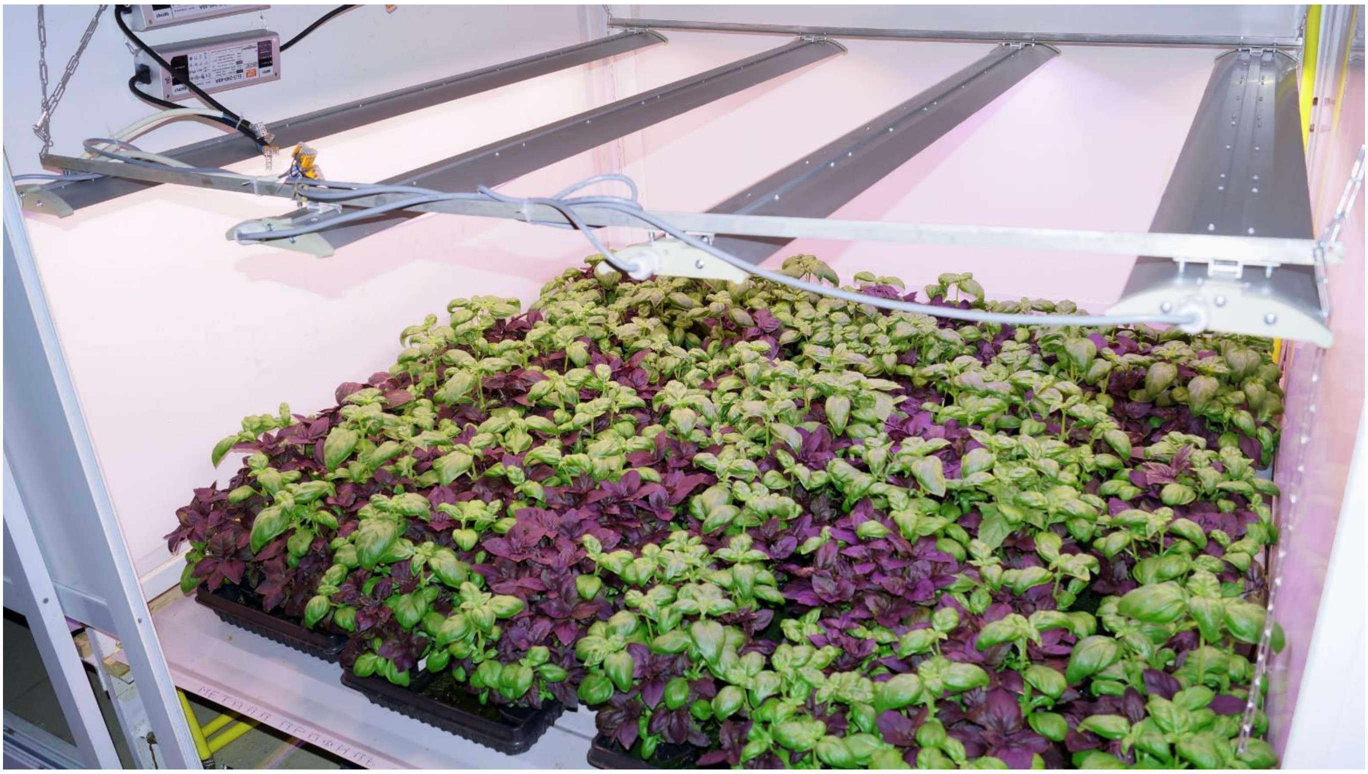
FLORA LED luminaires are recommended to be installed in the greenhouse with lines along the axis of symmetry of the trays (rows) with plants. For the installation of lamps in greenhouses, it is recommended to use trays, cables, busbars, using lamp brackets.







Пикировка 05.01.20
Посадка 29.01.20



Modules LED FARM

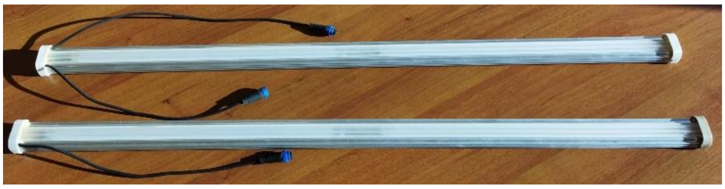
Application area

LED FARM modules are designed to create energy-efficient artificial lighting for plants when growing them on multi-tier (shelf) systems in protected ground cultivation facilities: “urban” (vertical) farms, phytotrons, greenhouses.

Design

LED FARM 40.0.X **LED FARM 80.0.X**

LED FARM 40.one.X **LED FARM 80.one.X**



Framemade of high quality aluminum minia. Has two versions.

Protective glassmade from stabilized UV resistant optical polycarbonate.

LEDs– high-performance LEDs: NICHIA (Japan) and Seoul Semiconductor (South Korea).

Side coversmade from durable poly measured material.

Fastening: hardware / corners / brackets.

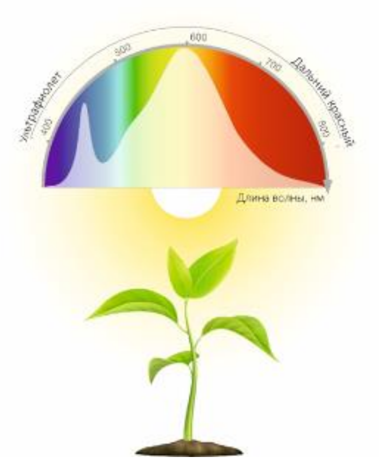
LED FARM modules have two designs that differ in the input (output) of the supply wire. In the module designation:

X=1 - the module has only an input wire; **X**=2 - the module has an input and output wire

Specifications

Parameter	Module designation			
	LED FARM 40.0.X	**LED FARM 80.0.X**	**LED FARM 40.1.X**	**LED FARM 80.1.X**
Input current direct (DC), A	1.4	1.4	1.4	1.4
Supply voltage, V	28	56	28	56
Power consumption, W	39	78	39	78
Radiation flux, W	19	38	19	38
Photon flux, μmol/s	92	184	92	184
Luminous flux, lm	6250	12500	6250	12500
Light distribution class	P	P	P	P
Light Intensity Curve Type (KSS)	D	D	special	special
Energy efficiency class	A+	A+	A+	A+
Protection class against electric shock	I	I	I	I
Degree of protection	IP65	IP65	IP65	IP65
Operating temperature range,$_0$C	+1...+30	+1...+30	+1...+30	+1...+30
Weight, kg	0.8	1.6	0.6	1.2
Overall dimensions, mm	585x134x33	1160x134x33	585x55x40	1160x55x40
Price, euro				

LED FARM modules are a source of light in the wavelength range of 380-780 nm, providing the course of the whole variety of photobiological processes inherent in plant organisms.



The nominal service life of the modules is 10 years with reliability indicators $L_{90}F_{ten}$≥60000 hours according to GOST R 56230-2014 (Russia) and IEC/PAS 62717:2011 (EU).

Warranty period of operation - 36 months.

Installation Recommendations

To increase the energy efficiency of rack-type phyto-installations, it is recommended to place the modules in the transverse direction of the rack system. With such a layout, the light fluxes of the modules are effectively used for irradiating agrophytocenosis, and the influence of the marginal zone with low irradiation on obtaining an economically useful crop as a result is reduced. This arrangement of modules is also more convenient for installation, maintenance and repair of lighting equipment.

Transverse arrangement of modules

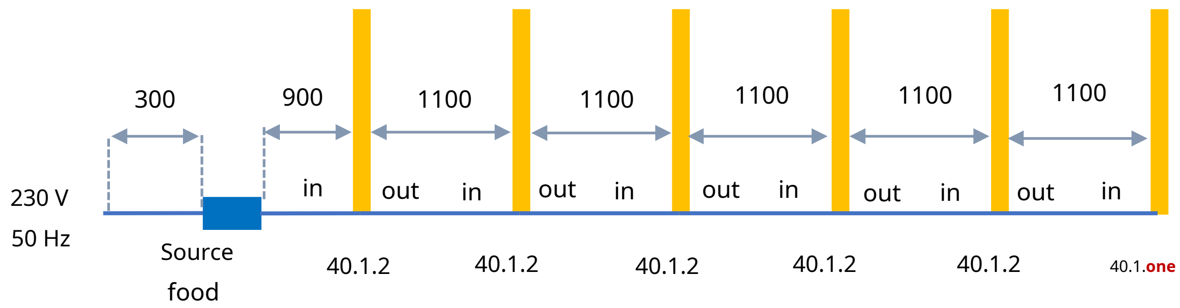
Longitudinal arrangement of modules

LED FARM modules are connected in series to each other in an electrical circuit and connected to an external power supply network through an AC - DC power source (driver) of the XLG-240-MA or XLG-240-M-AB type. Recommended delivery kits:

Name	Set #1	Set №2
Power supply XLG-240-MA (XLG-240-M-AB)	one	one
Module LED FARM 80.0.1 or LED FARM 80.1.1	one	-
Module LED FARM 80.0.2 or LED FARM 80.1.2	2	-
Module LED FARM 40.0.1 or LED FARM 40.1.1	-	one
Module LED FARM 40.0.2 or LED FARM 40.1.2	-	5

The kits may include fastening elements for modules on racks, connecting wires,
cable connectors and other materials and components agreed to be supplied within a specific project.

Length of connecting wires in mm in the basic delivery variant (default):



Step (spacing or**S**) is the distance between neighboring modules. It is recommended to install modules with step S = 60 cm.

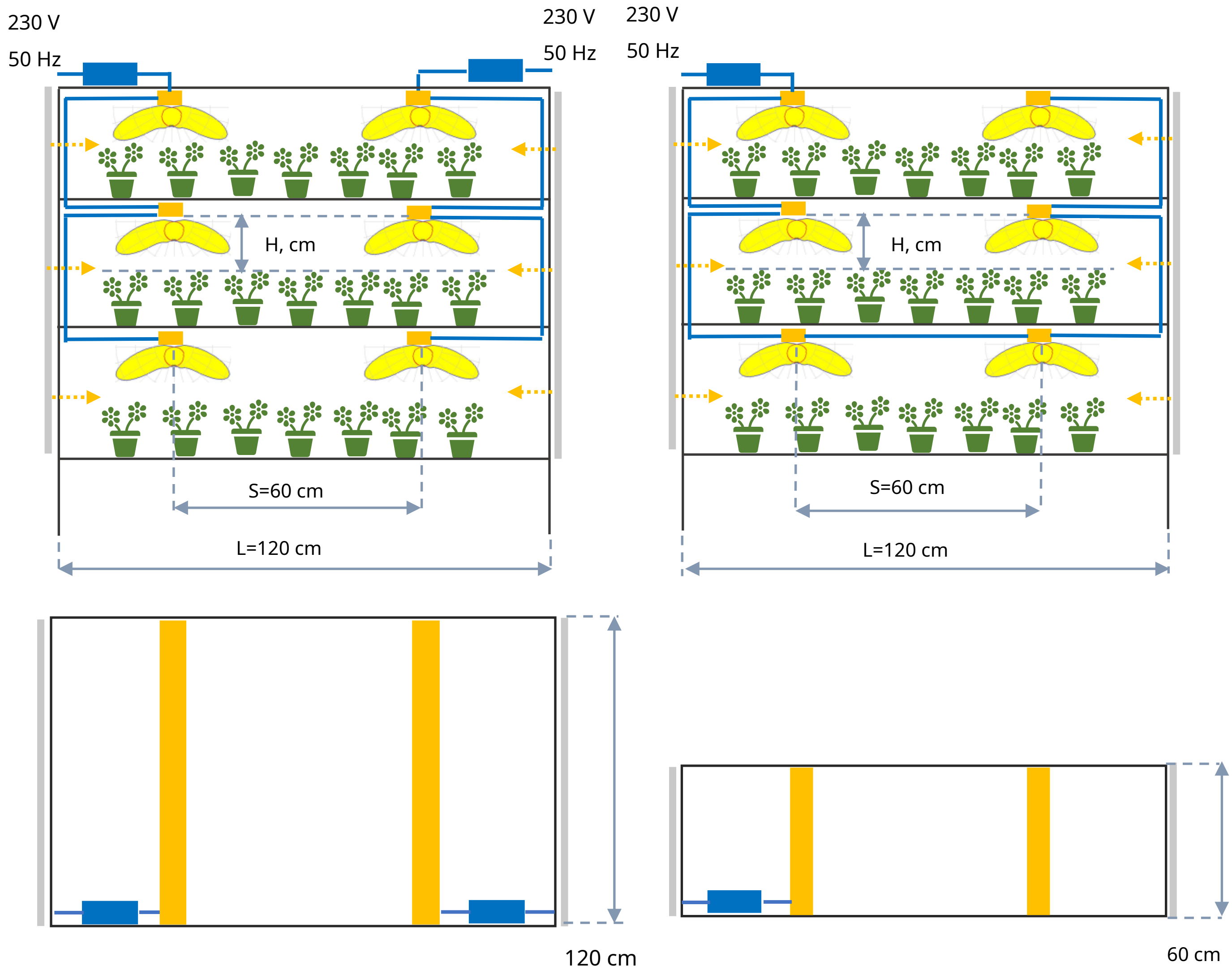
Mounting height (height or**H**) - the distance from the protective glass of the module to the agrophytocenosis (the upper part of the plants. It is recommended to install the modules at a distance from the tops of the plants:

LED FARM 40.0.X and LED FARM 80.0.X H=30cm

LED FARM 40.1.X and LED FARM 80.1.X H=15cm

To build a production line, it is recommended to use a shelving module with 3 shelves
120 cm wide and 120 cm wide. It is recommended to use set No. 1 on the rack module. Recommended: place the power supply on the top shelf; Place connecting wires along supports and shelves.

If it is necessary to use racks of a smaller width, it is recommended to use a rack muzzle with 3 shelves 120 cm long and 60 cm wide. It is recommended to use set No. 2 on the rack module.

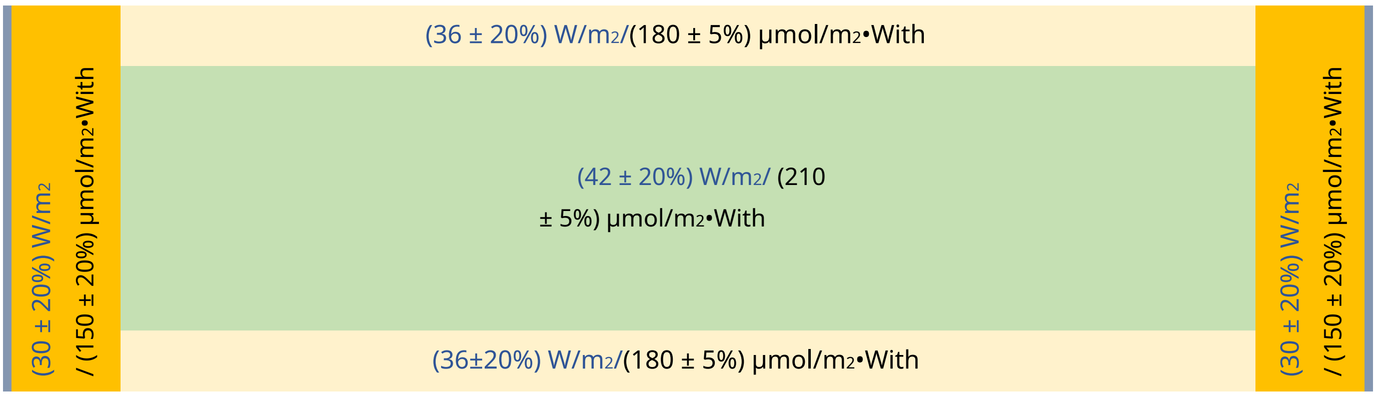


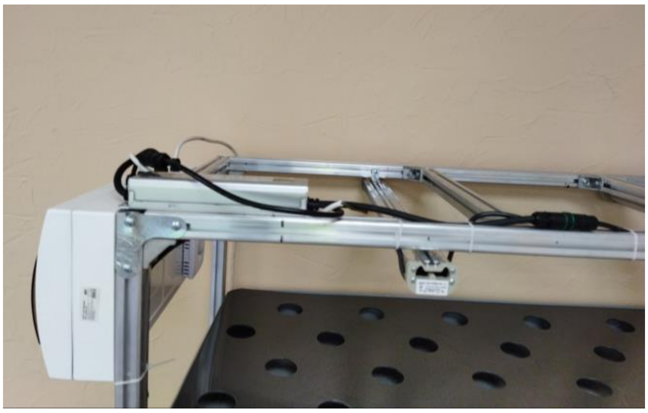
The production line equipped with LED FARM modules with 60 cm pitch has the following parameters:

- ➢ average irradiance of the growing area — $E_e \leq 40$ W/m2/$E_p \leq 200$ μmol/m2•s ≤ 120 W/m2
- ➢ specific installed capacity

Increasing the energy efficiency of a cultivation facility is possible by increasing the length of the production line, using several parallel lines, using room surfaces and reflective screens to redistribute radiation (photon flux) in order to increase the irradiation of agrophytocenosis.

Horizontal exposure in the growing area






Wiren Board 6


Wiren Board 6
Programmable Automation Controller

Terms and Definitions

Light occult cheers–macrotechnological process growing plants with a combination of natural and artificial lighting (greenhouses) or with completely artificial lighting

Greenhouse(industrial)– building with translucent structures (glass, less often film or polycarbonate) with a set of technologies and technical means that ensure climate control and plant nutrition and highly productive cultivation of vegetable, berry, flower and other crops ***city farm***–a new type of compact structures protected ground, located close enough to the residence of residents and intended, as a rule, for the installation of multi-tiered rack systems for growing plants

Eats venous (daylight) lighting– lighting, with where the light source is solar radiation

Artificial (electric) lighting – lighting with electric light sources ***Combined lighting***– acting jointly natural and artificial lighting ***Artificial plant lighting***(in buildings protected ground) - lighting / irradiation of plants using electrical sources of optical radiation

Phot period– duration of daylight hours (lighting)

growing season(for greenhouse plants) – time between planting the crop and completing the harvest

Irradiation device – device, destined for exposure plants in industrial greenhouses and other greenhouse cultivation facilities and containing one or more electric light sources and lighting fixtures

Irradiator co LED light – an illuminating device that uses LEDs as a light source

Control device (for light diodes) a device installed between the power supply network and one or more LEDs and designed to supply the LED with a rated voltage or current. It may include means for controlling the luminous flux, controlling the spectral composition radiation, power factor correction and radio interference reduction, as well as other controls

Rated power of the irradiator (W) is the sum of the rated power of the radiation source, used in the irradiator, and nominal power losses in the ballast (control device) of the irradiator

Efficiency of the irradiating device in the region of photosynthetically active radiation (μmol/s)– the ratio of the photosynthetic photon flux emitted by the device to that consumed by the device **power**

Irradiation installation (for cultivation plants)–set of radiation devices, supporting structures, power supplies and exposure management, as well as elements of the irradiated space involved in

redistribution of radiation (screens and surfaces of the room) or being the object of illumination (plants), functionally related to provide the necessary conditions for growing plants

Power irradiation installation **(W)** – total power, consumed everyone components irradiation installations (irradiators, power and control equipment, etc.)

Specific installed power(sources Sveta)– the ratio of the total nominal power consumed by all light sources of the irradiation installation, to the area of the planting site

Relative specific power of the irradiator– ratio of power consumed irradiation installation, to the product of the area of the planting area and the average energy or photon irradiation of this area

specific annual perspiration energy irradiation installation for a specific year (W*h/m2*G)– ratio of electrical energy, consumed by the irradiation installation during the year under consideration, to the area of the planting site.

System of energy quantities– set quantities expressed quantitatively in units of energy or power and their derivatives.

Energy quantities characterize light regardless of the properties of human vision ***The system of photon quantities***– set of values, expressed in units of the number of photons and their derivatives

Sweat ok radiation – power emitted, transmitted or received as radiation ***Pot ok fotos***is the ratio of the number of photons, emitted, transmitted or received in a short time interval, to this interval ***Energy irradiance (W/m2)***– relation flux of radiation incident on a surface element containing the point under consideration to the area of this element

Photon irradiance (μmol/m2*With)– relation the flux of photons incident on a surface element containing the point under consideration to the area of this element

Radiation (electromagnetic)–emission or transport of energy in the form of electromagnetic waves and associated photons
Optical radiation– electromagnetic radiation with a wavelength from 100 nm to 1 mm
Radiation energy, J–integral over time from radiation flux for a given period of time ***mole***– unit of measurement of the number of photons in relation to light culture of plants, equal to NA photons, where NA ≈ 6.02 * 1023 (derived unit micromole ≈ 6.02 * 1017)

Ultraviolet radiation optical ***(UV radiation)*** – radiation, length waves whose monochromatic components are less than the wavelengths of visible radiation. With regard to plant light culture, this is optical radiation with wavelengths shorter than 400 nm. Ultraviolet radiation is divided into three areas ***Ultraviolet A (UV-A) area***– the wavelength range from the short-wave boundary of the visible radiation region to 315 nm. With regard to plant light culture, this is the wavelength range from 315 to 400 nm

Ultraviolet B (UV-B) area– wavelength range from 280 to 315 nm
Ultraviolet C (UV-C) area– wavelength range from 100 to 280 nm
solar radiation– electromagnetic radiation sun

direct solar radiation– part of the atmospheric solar radiation, which in the form of a collimated beam of rays reaches the Earth's surface after selective attenuation by the atmosphere

Scattered sky radiation– part of the solar radiation that reaches the Earth as a result of scattering of radiation by air molecules, aerosol particles, cloud particles and other particles

Total solar radiation– set of direct solar radiation and scattered sky radiation

Photo osynthetically active radiation (PAR)– optical radiation in the range from 400 to 700 nm used by plants for photosynthesis, growth and development

"Blue" PAR area– wavelength range from400 to 500 nm

"Green" area of the PAR– wavelength range from500 to 600 nm
"Red" region of the PAR– wavelength range from600 to 700 nm
Far red light– wavelength range from 700 to 800 nm

Infrared radiation (IR radiation)– optical radiation, monochromatic wavelengths
whose components are longer than the wavelengths of visible radiation. With regard to plant light culture, this is optical radiation, whose wavelengths lie in the range from 800 nm to 1 mm. Infrared radiation is divided into three areas ***Infrared area A (IR-A)***– range wavelengths from the long-wave boundary of the visible radiation region to 1400 nm. With regard to plant light culture, this is the wavelength range from 800 to 1400 nm

Infrared B (IR-B)–range wavelengths from 1400 to 3000 nm

Infrared region C (IR-C)– range wavelengths from 3000 nm to 1 mm