SPECTRAL ILLUMINATION EQUIPMENT FOR GREENHOUSE PLANTS

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Abstract. It is important to develop such greenhouse constructions and their exploitation technologies which would let to gain maximum harvest with minimal expenditure of electrical and heat energy. In order to reach the preceding statement, it is important to understand properly also the reaction of plants towards the artificial physical field and the impact of other external factors. For this reason an electrical scheme for the radiation of plants with spectral low-pressure bulbs of gas disruptive discharge and incandescent bulbs in dark heat source regime is offered. Also a device of plant radiation, heating and watering is developed where as the spectral luminescent light bulb ballast resistance in the technique of light for the first time a construction of closed water tank serves which simultaneously performs the function of heating apparatus. Examination is performed on the influence of optical radiation and temperature on the process of plant development.

Keywords: neutral point displacement voltage, spectral illumination.

Introduction

From all living organisms on Earth only plants and some microorganisms have the ability to transform light energy to energy of chemical bonds. That is done in the photosynthesis process and it needs solar radiation. The main pigment of photosynthesis is chlorophyll presented in all photosynthetic organisms. Chlorophyll absorbs white light selectively, therefore the photosynthesis process requires defined light spectrum [2, 3].

The main light factors influencing photosynthesis are light spectrum, intensity, diurnal and seasonal variations. [1, 2]

Light energy influences almost all the aspects of plant life directly and indirectly. Thus, it controls the plant structure, form, shape, physiology, growth, reproduction, development and local distribution. For direct influence photosynthetically active radiation (PAR) plays the main role - wavelength of light between 400 nm and 700 nm is most effective. Comparatively more photosynthesis occurs in red and blue regions. In both these regions light is absorbed by chlorophylls. Indirect influence is realized by radiation 300-800 nm and called physiologically active radiation. Different pigment systems are involved in absorbance of spectrum. All photoreceptors operate as light-induced initiators of signaling pathways leading to varying phenotypic expressions at various levels and stages of plant development. Photoreceptors are involved in light-regulation of germination, de-etiolation, photomorphogenesis, shade avoidance, phototropism, chloroplast movement, stomatal opening, circadian entrainment, flowering, stem elongation, gene expression, and protein (enzyme) activity. The main of them is phytochrome characterized by a red/far (λ = 730 nm) – red (λ = about 660 nm) photochromicity. Many flowering plants use it to regulate the time of flowering based on the length of day and night (photoperiodism) and to set circadian rhythms, elongation of seedlings, the size, shape and number of leaves, synthesis of chlorophyll, and the straightening of the epicotyl or hypocotyl hook of dicot seedlings. Phytochrome is localized also in seeds and influences seed germination. Red light stimulates, but far-red-inhibits seed germination [1-4].

Blue light (λ = 400-500 nm) also mediates plant growth and development thanks to another pigment – cryptochrome that regulates germination, elongation, photoperiodism, and other responses in higher plants. Cryptochrome is involved in the circadian rhythm of plants. Blue light decreases stem and hypocotyls' elongation, determines phototropical response [2, 4].

Ultraviolet waves (315-380 nm) suppress plant elongation and stimulate biosynthesis of vitamins.

Only yellow (595-565 nm) and green (565-490 nm) light waves have no effect on plant growth

Providing of optimal light and thermal regime in winter months, seedling growth can be decreased twice. The optimal ratio between temperature and light for various plants is different [1-4].

Materials and methods

In accordance with the preceding information the qualities of needed radiation spectrum shall be binding in the right choice of artificial lighting devices.

For example, when using a lamp with sulphur spectrum unnecessary to plants the electrical energy is consumed irrationally.

For salvation of this issue an electrical scheme [5] (Figure 1) was developed, which may be used for the radiation of greenhouse plants with spectral low-pressure gas bulbs and incandescent bulbs in dark heat source regime.

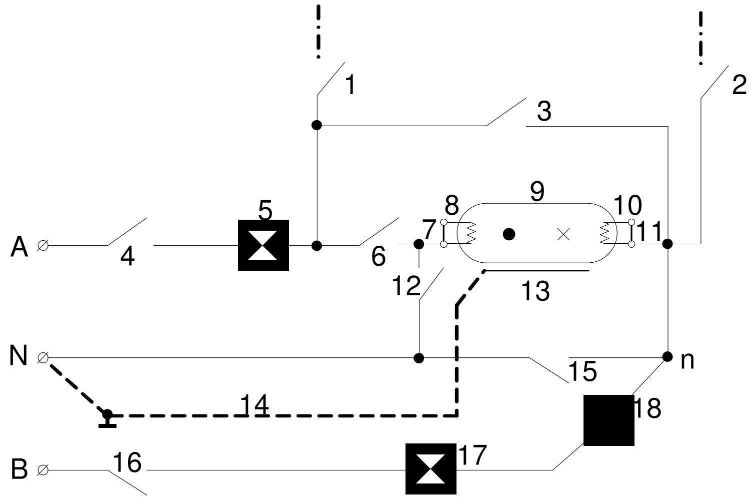

Fig. 1. **The scheme of one autonomic block electric junction**

Electric scheme operates as follows: the switches 4, 6 and 16 are in locked but the switches 1, 3, 2, 12 and 15 in unlocked position. The fluorescent light bulb 9, which transforms in the visible light of ultraviolet rays, receives full line voltage (380 V) and blazes up easily with in a row joined ballast incandescent bulbs 5, 17 and 18.

After blazing up the fluorescent light bulb 9 and lighting the incandescent bulb 5 light at their nominal exploitation voltages, but the incandescent bulbs 17 and 18, receiving reduced voltage drop, turn into dark warmth sources and mostly generate only infrared rays.

When the switch 12 is switched on a diphase three-wire system is made where on different phase voltages the lighting illumination incandescent bulb 5 and fluorescent light bulb 9 and ballast incandescent bulbs 17 and 18 are locally attached.

Thereafter the switch 6 is switched off and the circuit of the incandescent bulb 5 is discontinued, simultaneously lighting the fluorescent light bulb 9 is over-switched to autonomous mono-phase feeding with the incandescent bulbs 17 and 18 as ballast resistors.

Then alongside a circuit junction of all incandescent bulbs wired up to the line voltage is made, but the lighting fluorescent light bulb 9 without any kind of ballast resistance is over-switched to neutral point displacement voltage amid the lighting incandescent bulb 5 and a junction point of the incandescent bulbs 17, 18 which generate infrared rays and a neutral point of an electrical power network.

By switching off the switches 16 and 15 while the switches 1, 2, 3, 4, 6 and 12 are in unlocked position and light only the incandescent bulbs 17 and 18 a discreet heating regime is created. Heat delivered by these bulbs greatly rises the temperature in greenhouse air and soil.

For gaining selective fluorescent lighting the bulb 9 receives its electro-feeding from an analogous greenhouse (not included in figure) situated in another place, in its running regime through locked switches 1, 2 and 6 at unlocked switches 3, 4, 12, 15 and 16 in addition fluorescent light bulb circuit is switched off in the greenhouse which produces electro-feeding. From this regime it is possible to over-switch the fluorescence light bulb to feeding from neutral point displacement voltage with the help of the switches 3, 6 and 12 in the order mention above. Analogically – electro-feeding for creating selective fluorescent rays, from the greenhouse described above to another greenhouse, can be delivered by switching off the switches 1, 2, 4 and 16 and switching on the switches 3, 6, 12 and 15.

Results and discussion

In the new device a circuitry is created, its technical advantage of exploitation is in possibility to repeatedly over-switch the lighting fluorescent light bulbs for creation of the needed plant lighting, exposure and heating regimes. Improved running of fluorescent light bulbs from line voltage broadens their range of classification as well as multiplies versions of varying optical rays with spectrally dosed apparent light and/or spectrums of infrared rays. Since fluorescent light bulbs and incandescent bulbs are joined in autonomous blocks (Figure 1) common circuitry of the greenhouse allows to manipulate with the described regimes in a quite wide range in order to create optimal microclimate conditions for growth of various plants.

A device for plant exposure, heating and watering is also developed where as low-pressure gas disruptive discharge bulb ballast resistors for the first time in the light equipment a construction of closed water tank serves (Figure 2).

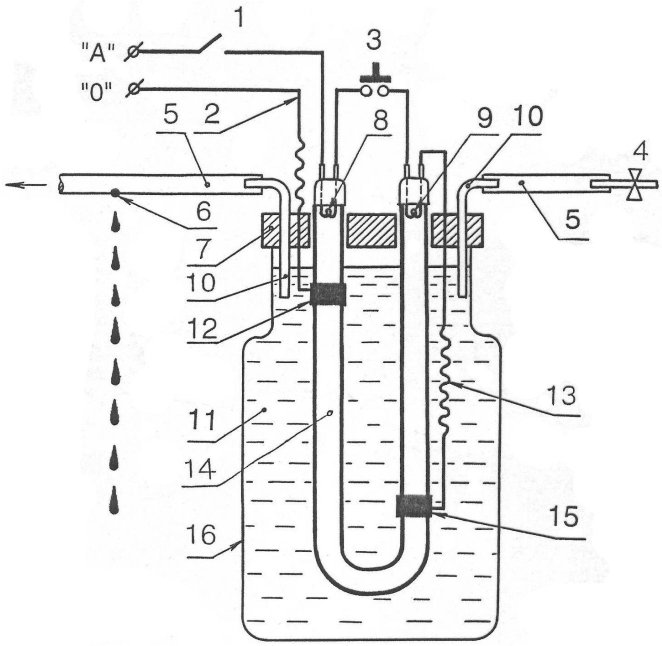

Fig. 2. **Artificial plant lighting and watering device**

In the proposed device luminescent bulbs of types “U” or “W” 14 shall be inserted into the transparent, electro-insulating tray (glass, plastic) 16 filled with the water 11. On the part of the bulb’s tube located in the water shifting little metallic contact plates 12 and 15 are set. The water layer between these plates performs functions of the adjustable hydro resistive ballast resistor whereas the tray itself serves simultaneously as an armature of the luminescence bulb and a heating corpus.

As already known [7] a luminescent bulb embraced by water increases its light return for 1.5 to 2 times and improves running conditions because indirectly it performs also the extra ignition electrode role. Performance of luminescent bulbs depends on the environment temperature [5], therefore it is possible to create optimal exploitation regimes by heating water up to the appropriate temperature.

The device is constructed as follows. At one of the outputs of the luminescent bulb electrodes which are not placed in water a phase cord “A” is attached, at the other – a waterproof insulation cord 13 from the contact plate 15. The contact plate 12 with the help of the cord 2 is attached to the null-cord of the electrical power network “0”. Between the other two outputs of the bulb electrodes the contacts closing button 3 is attached.

In order to maintain the needed temperature around the tubes of the luminescent bulbs 14, with the help of the valve 4 adjustable water flow in the tray 11 is attached.

In the watering system rubber or plastic tubes 5 (at least 1m long) are used which eliminate appearance of dangerous electric potential on the device's metallic parts which usually do not convey the current. These tubes are densely connected with the tray 16 caps 10 fixed in a screwed plastic lid 7. Drop-watering with heated water is performed through locally made perforation joints 6 along the whole length of the tubes 5.

When adding appropriate pigment to the water it is possible to radiate plants also with red and/or blue light spectrums, but to use treated colored water for the change of blossom pigmentation by diffusion.

The electric scheme of the device performs as follows. Switching off the switch 1 the luminescent bulb receives full phase to neutral voltage on to the cold end electrodes 8 and 9 throughout the ballast resistive hydro-resistor formed in water layer between the contact plates 12 and 15. The connecting contacts of the running buttons 3, glowers of electrodes heat up, thus promoting the bulb's 14 blazing up in the moment of its tripping.

Conclusions

1. The developed plant electrical scheme of spectral lighting [5] the main advantage of which is an opportunity to repeatedly over-commute burning fluorescent bulbs in necessary formation of plant light, radiation and heating regimes. Improved running of fluorescent light bulbs from the line voltage widens their diapason of classification as well as increases variants of modifiable optical radiation with spectrally dozed apparent light and/or spectrums of infrared radiation.
2. Unification of the construction of the device [6] reaches 20 % with the simultaneous reduction of capital investments by 25 %. Increase of the light yield [7], gained by the influence of the water layer covering the bulb tubes, gives the 30 % economy of energy resources.
3. Prototypes of plant illumination systems have been tested at the growing chambers of the Institute of Soil and Plant Sciences.

References

1. Gussakovsky E.E., Shahak Y., Schroeder D.F. Color of illumination during growth affects LHCII chiral macroaggregates in pea plant leaves. Journal of Photochemistry and Photobiology B: Biology, vol. 86, issue 2, 2007, pp. 121-130.
2. Березина Н.А., Афанасьева Н.Б. Экология растений (Ecology of Plants). Москва: Академия, 2009. 400 p. (In Russian).
3. Lambers H., Pons T.L, Chapin F.S. Plant Physiological Ecology. 2nd revised edition. New York: Springer-Verlag Inc., 2008. 640 p.
4. Scott P. Physiology and Behaviour of Plants. Hoboken, NJ: John Wiley, 2008. 305 p.
5. Fridrihsons J. Portatīvās siltumnīcas variējama optiskā starojuma iekārta (Variable optical radiation equipment for portable greenhouse). Patent No. P-09-69, date of submission 06.04.2009. (In Latvian).
6. Fridrihsons J. Augu mākslīgās apgaismošanas un laistīšanas iekārta (Artificial lighting and watering equipment for plants). Patent No. LV 11655 B: date of publication 20.06.1997. Patenti un Preču Zīmes, No. 6 (1997), 238 p. (In Latvian).
7. Справочная книга по светотехнике (Lighting Technical Manual). Под ред. Ю.Б.Айзенберга. Москва: Энергоатомиздат, 1983. 472 p. (In Russian).