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# Mobile installations for electro treatment of soils and plants with the use of photovoltaic systems as power supply

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**Abstract.** The technology of electro processing by UV- radiation for cultivation of cotton is considered. By results of experimental researches optimum parameters for treatment soils with ultraviolet radiation lamps for increasing the accumulation of the most mobile nitrate forms of nitrogen are defined. Prospects of transition of UV-lamps to light-emitting diodes (LED) as way of improving efficiency of processing, and creation of independent power supply by means of photo-electric batteries are shown.

## 1. Introduction

In the world practice of plant growing, in order to reduce the volume of applied artificial mineral fertilizers, the search for effective plant growth stimulators is being carried out [1, 2, 3, 4]. The experience of research in the field of electrical processing allows us to consider an alternative way to increase the productivity of agricultural crops based on the impact of artificial ultraviolet (UV) radiation processes on objects (seeds, plants, soil), taking into account the environmental requirements of the maximum permissible radiation parameters [1, 2, 5]. To achieve the desired result, in the process of UV treatment, each particle of the irradiated volume is transferred an amount of energy not less than the minimum allowable value (radiation dose) specified by the technological conditions of the UV installation [1, 2, 6].

The positive effect of ultraviolet radiation is mainly existed at high temperatures and a level of visible light illumination, which is associated with better repair (restoration) of cell damage under these conditions [7]. Ultraviolet light affects the photoperiodic reactions of plants. Thus, optimal doses increase the number of congested flower buds [8]. A general rule has been determined for calculating effective doses - the less direct light falls on plants in nature and the lower it grows, the more it will be damaged by the same doses of ultraviolet radiation [9]. The dose is calculated ($\tau$ is the exposure time) as

$$D = I_0 \cdot \tau \qquad (1)$$

The units of radiant exposure in SI are joule per square meter (J / $m^2$) with the dimension of power, since in SI the solid angle has zero dimension. Correspondingly in SI: watts per steradian (W/sr). For lamps, the energy flux in a light wave I0 can be expressed in W/$m^2$, in which not only the intensity of the light source is significant, but also the spectral distribution of this intensity [10].
By international agreement, the unit of luminous intensity is a candela, equal to the intensity of light in a given direction of a source emitting monochromatic radiation with a frequency of 540 × 1012 Hz (l = 555 nm), the energy intensity of light radiation of which in this direction is 1/683 W/steradian [11]. It is equal to the luminous intensity of a point source in the direction in which it emits a luminous flux of 1 lumen, evenly distributed in a solid angle of 1 steradian [12].
As the analysis of publications shows, most studies on the study of the effect of ultraviolet radiation on plants concern the harmful effect of the increased short-wave radiation due to the destruction of ozone in the atmosphere. At the same time, a distinction is made between short-wave UV radiation - with a wavelength of 200 to 280 nm (the so-called UV-C), medium-wavelength - 280 ÷ 315 nm (UV-B) and long-wavelength - 315 ÷ 380 nm (UV-A).
Radiation with different wavelengths affects plant cells in different ways. UV-C radiation in the cell affects DNA, UV-B - mainly proteins. UV-A mainly has a phytoregulatory effect and determines the change in the metabolism of plant tissues under stress [8], which causes increased growth in a wide group of plants. For example, cotton plants become larger by 30 ÷ 50%. Flowering also occurs earlier [5].

## 2. Research Methods

Figure 1 highlights the energy flux of ultraviolet radiation per unit surface which is determined by the formula:

$$I_0 = I/d^2 \tag{2}$$

The illumination of a lamp depends on its type (incandescent lamp, fluorescent lamp, LEDs) and is determined by the formula [13]:

$$I = N \cdot I_{1Wt} \tag{3}$$

here $N$ - the lamp power,, $I_{1Wt}$- the specific light output of the lamp.

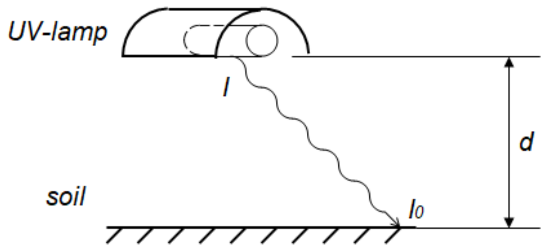


**Figure 1.** Luminous flux values when rays directed from ultraviolet lamps to the soil

According to Wien's law, the wavelength of the maximum radiation intensity is inversely proportional to the absolute temperature and is equal to 2900/$T$ ($T$ is absolute temperature). In solar radiation (6000 K), the proportion of ultraviolet radiation is no more than 5%. The intensity of biologically effective UV radiation for radiation types A, B, C, respectively, is 0.15, 0.29, and 0.45 W/$m^2$ [14].
Incandescent lamps and gas-discharge lamps are used as sources of ultraviolet radiation. The filament temperature of conventional tungsten incandescent lamps is about $2500^0$K. The use of UV lamps makes it possible to increase the value up to about 1.0 Wt/$m^2$ in the short-wave and medium-wave parts of the spectrum and 5÷6 Wt/$m^2$ in the UV-A spectrum [15]. The exposure (dose) of UV irradiation when the tractor passes the area should be up to 120 J/$m^2$, because in this case the plant is not stressed [16].

Installation of electrical treatment of agricultural crops, consisting of two lamps, is mounted on the buffer of the tractor. Depending on the growth of the plants, the number of its leaves and the cultivated rows, they are set at an angle from $0^0$ to $85^0$ to each other. The UV lamps are powered by a tractor generator or battery (12 VDC) through a special ignition and power system that converts and delivers 220 VAC when output is required.
The purpose of the field tests carried out at the experimental field base "BMKB-Agromash" (Tashkent region) was to identify changes in soil processes under the influence of periodic irradiation with ultraviolet irradiation under different factors of the experiments. In this case, the selection of the optimal lamp power was carried out.
Nitrogen has a special place in plant life. It is part of proteins, nucleic acids, chlorophyll, acetophenone, as well as a number of cell centrobolites. At the same time, plants absorb inorganic nitrogen in nitrate form. The plant is very sensitive to the wavelength of ultraviolet radiation. When a DNA solution in acetophenone is irradiated with light with a wavelength of 350 nm, quanta are absorbed only by the sensitizer [17].
Under the influence of ultraviolet light, colored organic substances are able to add oxygen even in molecular form [18]. This is directly related to biological activity and soil fertility, because the humus contains amino acids that can inhibit the activity of soil enzymes. This photomethylation changes the number of functional groups, which affects the colloidal-chemical properties of humus.

## 3. Results and Discussion

*3.1. Results of treatment a soil*

According to the research results, treatment with ultraviolet radiation lamps can significantly increase the accumulation of the most mobile nitrate forms of nitrogen, which provides an additional increase in plant productivity [1, 19]. Comparison of their content in soil layers shows that it is characterized by the movement of matter with ascending streams of soil moisture, which is usually observed in arid regions, when, during the period of hot dry weather, moisture begins to intensively evaporate from the soil surface.
To identify the importance of every elements of electrical treatment with ultraviolet radiation, statistical methods were used to process experimental data. Figure 2 shows the arable layer (0 ÷ 30 santimeters) for the nitrogen content in the plant, a maximum is observed at an ultraviolet lamp power of 60 W.

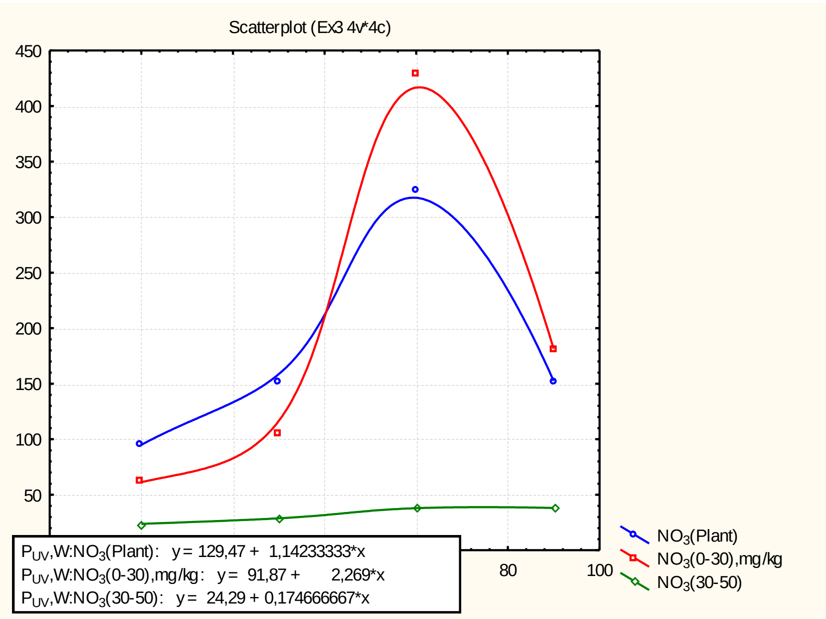


**Figure 2.** Regression equations for the dependence of the nitrate nitrogen content in the flowering phase of a plant on the power of the UV lamp

The next important technical parameter of ultraviolet lamps is the optimal wavelength of radiation. During the growing season, cotton plants were exposed to UV irradiation three times before watering: the appearance of 3-4 leaves, budding, flowering. Comparison of research results shows that there is an increase in nitrogen consumption by plants during the flowering period. The use of UV irradiation of seeds leads to additional mobilization of nutrient reserves in the soil by the plant in the final stages of development [20].

The results are given that determine the effect of treatment modes with ultraviolet radiation of seeds at the following exposure values: 24; 48; 72; 96; 120 W·s/m$^2$ with wavelengths 248, 280, 302, 313, 334 and 365 nm. The results of the experiments obtained at the wavelengths of 248 and 280 nm were lower than the data obtained in the control at 365 nm. It is shown that a deviation of 21.84 nm from the optimal wavelength and 28.77 W·s/m$^2$ from the optimal exposure level can cause a deviation of 5% in the efficiency of electro-treatment with ultraviolet radiation, in particular for seedlings.

### *3.2. Technic-economical evaluation UV-LED with PV electro supply*

Recent developments in the field of lighting technology make it possible to begin replacing traditional incandescent lamps with modern solid-state UV sources, which are based on the ability of semiconductor materials to emit. In LED lamps, it is possible to obtain the maximum concentration in the required parts of the radiation spectrum [21].

In this case, the luminous flux per unit of lamp power is obtained by several tens of orders of magnitude, and there is no unwanted infrared zone in the radiation spectrum, which can lead to overheating of plant leaves. The only disadvantage of UV LEDs in comparison with lamps is the high price. However, in the future, the price of LEDs - the main component of the UV block in terms of cost - will decline.

Figure 3. shows the lighting characteristics of UV LEDs with a wavelength of 365 nm (± 5 nm), which have an acceptable power for finished devices in comparison with traditional UV lamps.

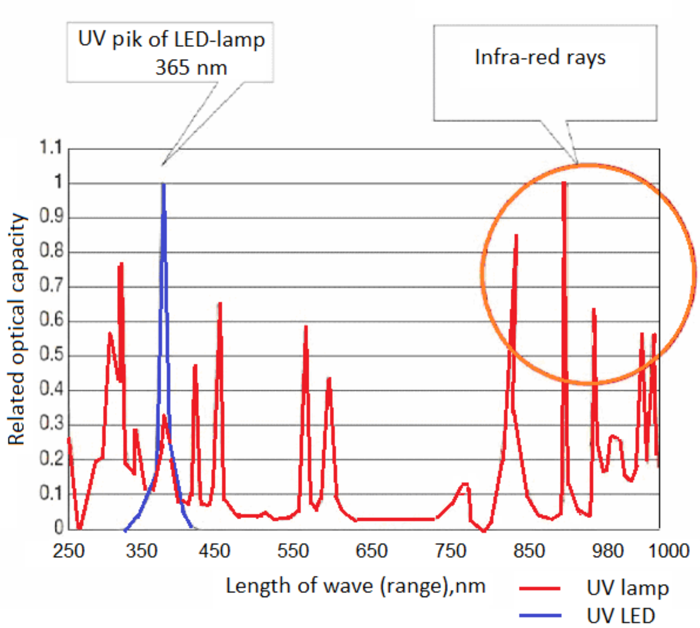


**Figure 3.** Comparison of radiation from conventional UV lamp and UV LED (AllnGaN)

In addition, even at the current price for UV LEDs, the technical parameters given in Table 1 show the economic feasibility of using LEDs instead of traditional lamps, because they have a significantly longer service life [22]. When using UV LEDs based on gallium nitride nanostructures as radiation sources, we obtain the following indicators and advantages in comparison with traditional lamp sources of UV radiation.

**Table 1.** Technical parameters the main types of lamps (incandescent and fluorescent), light-emitting diodes (LED)

| Typical parameters | UV LED | UV lamp |
|---|---|---|
| Radiation spectrum | narrow | wide |
| Efficiency, % | 15÷20 | 0,5÷1 |
| Power consumption at the same output radiation power, W/h | 100÷400 | 1000÷4000 |
| Time to reach operating power (switching the device on and off) | 0,1 seconds | 2÷3 minutes |
| Service life, hours | 40 000÷60 000 | 600÷1000 |
| Harmful substances | No | Emission of ozone at time of work |
| Infrared range (IR) radiation e | No | Most of the radiation in the IR range |
| Working temperature, $^0$C | 25÷30 | 600÷800 |

In addition, in comparison with the main types of lamps (incandescent and fluorescent), light-emitting diodes (LED) have the following features:
- Use energy economically compared to previous generations of electric light sources - arc, filament and gas discharge. So, the luminous efficiency of LED lighting systems with a resonant power supply reaches 132 lumens per watt of lamp power.
- LED ultraviolet lamps, in comparison with incandescent lamps, differ in that they do not cause chemical processes in plants to convert ferric iron into ferrous, thereby excluding the stress reaction of plants [7].
- Fluorescent lamps have a light output of 60 ÷ 100 lumens per watt, and incandescent lamps - 10 ÷ 30 lumens per watt (including halogen).
- With the optimal circuitry of power supplies and the use of high-quality components, the average service life of LED lighting systems can be increased to 50 thousand hours, which is 30 ÷ 60 times more compared to mass incandescent lamps and 4 ÷ 6 times longer than that of fluorescent lamps.
- Ability to obtain various spectral characteristics without the use of light filters (as in the case of incandescent lamps).
- Safety of use, i.e. absence of mercury vapors (in contrast to gas-discharge fluorescent lamps and other devices), which excludes mercury poisoning during processing and during operation.
- Small size and high strength.
- Unlike fluorescent lamps, in which the power consumption increases with warming up, for LED lamps with warming up, the power consumption drops to 30% while maintaining the brightness, this is due to a decrease in the voltage drop of the LEDs with warming up.
- Low temperature limit: high-power lighting LEDs require an external heatsink for cooling because they have an unfavorable size-to-heat ratio (they are too small) and cannot dissipate as much heat as they emit (despite even being more efficient than incandescent lamps ), which requires a passive radiator.
- A low voltage DC power supply is required to power the LED from the mains, during design are limited to a rectifier, and the LEDs are connected in series.

It is advisable to use photovoltaic batteries as low-voltage power supplies. This will ensure the autonomy of the power supply of the UV irradiation unit, which is important for a mobile system. At the same time, the OSRAM ultraviolet LED lamp with a power of 19 watts and a voltage of 12 volts exceeds the level of irradiation of a conventional lamp by 60 watts. Despite the higher cost of about $ 200 compared to the usual one, due to a significantly longer service life of 60 ÷ 100 times, LED lamps are more economical.

Such LED lamps are at the same time compact compared to traditional ones. They can be located in the headlights of the tractor.

Bulky and energy-intensive converters are not used as intermediate elements:
- from DC to AC,
- from a lower 12 V to a higher voltage of 220 V.

This significantly improves the reliability of the power supply of ultraviolet lamps, thanks to the use of a direct connection to DC sources. This also increases the overall efficiency of the installation due to the elimination of losses in the intermediate links.

## 4. Conclusions

The use of low-voltage power supply systems makes it possible to significantly simplify operation and ensure complete safety for personnel servicing plant electrical processing installations.

Since the power of LED lamps is low compared to traditional ones, they do not require large areas of PV panels to receive solar radiation to power them. Photovoltaic cells can be placed on the roof of the tractor cab using an air conditioner to cool the rear surface of the silicon PV panels.

Thus, the use of ultraviolet LED lamps for electrical processing in plant growing makes it possible to effectively use PV panels for their power supply, which generate electric current from solar energy. This opens up great prospects for the introduction of such systems in the farms of the republic

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