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THEORETICAL INVESTIGATION OF THE ELECTROPHYSICAL PROPERTIES OF RICE SEEDS AND THEIR SPROUTED SEEDLINGS

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Abstract. This article theoretically investigates the electrophysical properties of rice seeds and the seedlings that sprout from them. The study analyzed bioelectrical processes occurring in rice seed cells, including indicators such as membrane potential, ion exchange, electrical resistance, dielectric permittivity, membrane capacity, and complex resistance. Additionally, the influence of ultraviolet rays (UV) and electroactivated water (EAW) on the electrophysiological state of rice seeds and shoots has been theoretically substantiated. A fundamental scheme for treating rice seedlings with ultraviolet rays has been developed, and the relationship between the main radiation parameters - lamp power, treatment time, and radiation surface—has been determined. The obtained theoretical results showed that treatment with ultraviolet rays increases the permeability of cell membranes, activates physiological processes, and has a positive effect on the germination of rice seeds and the growth and development of shoots.

Key words: rice seeds, rice sprouts, electrophysical properties, ultraviolet rays, membrane potential, dielectric permittivity, electrical resistance, complex resistance, bioelectrical activity, agroelectrotechnology

Introduction. Studying the electrophysical properties of rice seeds is crucial for understanding the electrical activity of biological systems. Bioelectric phenomena occurring in the cells of rice seeds, such as membrane potential, ion flows, and electrical signals, are important indicators that express their physiological reactions to the external environment [1, 2]. The analysis of these phenomena serves as an important factor in determining the reaction of rice seeds to various environmental stress conditions. In particular, based on the bioelectrical indicators of rice seeds, it is possible to assess their level of stress resistance and determine the effectiveness of breeding and agrotechnical measures. It has the property of adapting to the external environment through the spread of current and changes in its potential within the tissues of rice seeds. Their electrophysical state depends mainly on the degree of polarization of the cell membrane, ion movement, and osmotic pressure; the potential generated on the cell membrane is 70–120 mV, which plays an important role in signal transmission by rice seeds.

Research methods. External factors, including temperature, humidity, and light, significantly affect the electrophysiological activity of rice seeds [3]. The membrane potential for rice seeds is formed based on the distribution of ions between the internal and external environments of their cells. This potential can be expressed using the Nernst equation as follows

$$E_k = \frac{RT}{ZF} \ln \frac{K^+}{K^+}, \qquad (1)$$

where E_k – Nernst potential for potassium ions, mV;
R – gas constant, R=8,314 J/mol·K;
T – temperature, K;
Z – ionic charge, Z = +1 for K^+;
F – Faraday constant, F = 96485 F/mol;

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$[K^+]$ – concentration of potassium ions in the external and internal environment, mol/L.

UVBs increase ion permeability in the cell membranes of rice seeds, which is expressed by the following formula

$$R_m = \frac{U}{I}, \qquad (2)$$

where U – voltage, V;

I – current intensity, A.

In addition to increasing ionic permeability in the cell membrane, UVN stimulates electron movement and, as a result, leads to changes in membrane resistance Rm, electrical capacitance C, and electrical potential [4].

Biological membranes behave like a thin film with dielectric properties, acting as a capacitor, meaning they have an electrical capacitance between two charged layers (the inner and the outer). This can be expressed as follows:

$$C_m = \varepsilon_u \ \varepsilon_0 \frac{S}{\delta}, \qquad (3)$$

where C_m – membrane capacity, F;

ε_u – relative dielectric permittivity of rice seeds, ε = 7-10;

$\varepsilon_0 = 8{,}85 \cdot 10^{-12}$ F/m – dielectric constant;

S – membrane surface, m^2;

δ – membrane thickness, m.

The essence of this formula is that membrane capacity directly affects the distribution of ions within the cell.

The rate of propagation of electrical signals and the change in membrane potential depend on its capacitance. When rice seeds are treated with UVB, changes occur in their membrane structure, leading to a change in the capacity value.

The latter is an important factor for studying the mechanisms of biophysical reactions [5].

Figure-1. shows a graph of the surface-dependent change in membrane capacity when processing rice seeds with UVB radiation.

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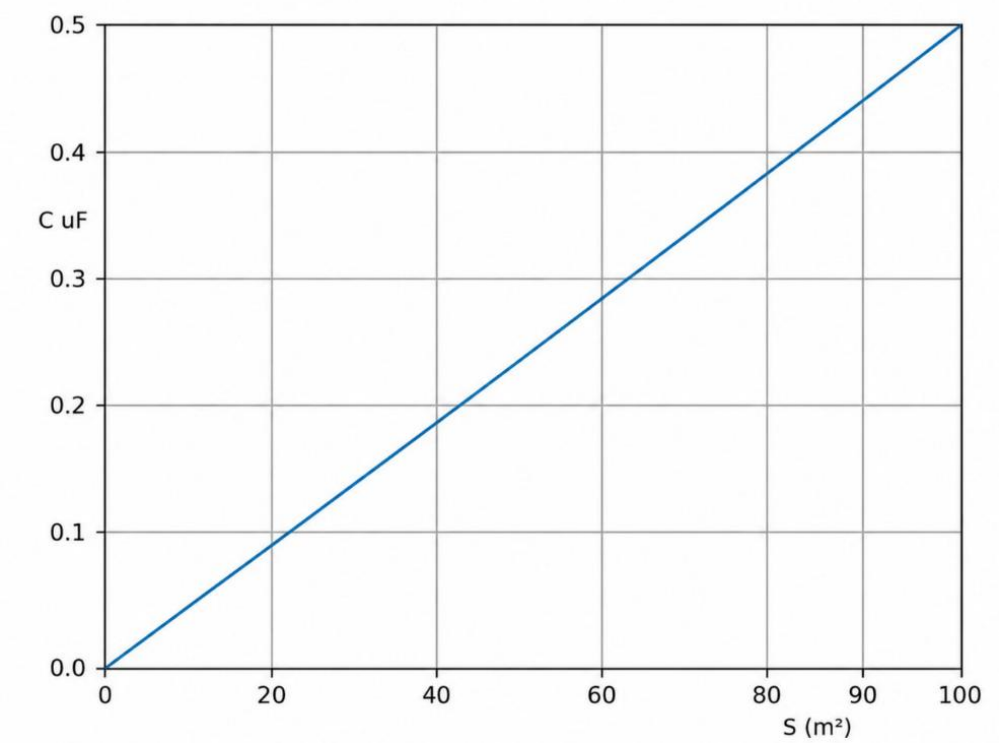


Fig. 1. Graph of the surface-dependent change in membrane capacity during UVA treatment of rice seeds.

One of the most important indicators in measuring the electrophysical properties of rice seed tissues is electrical resistance and dielectric permittivity. The main factors influencing these parameters are the structural state of cell membranes, the concentration of ions in the cytoplasm, and external influences, including ultraviolet rays. This process can be expressed by formulas.

1. 1. Electrical resistance [6]

$$R = \rho \frac{L}{A}, \qquad (4)$$

where R – electrical resistance of rice seeds, Om;
ρ – specific resistance of seeds, Om/m;
L – direction of measurement, m
A – cultivated area, m^2.

2. Kompleks qarshilik [6]

Using this formula, it is possible to determine the electrical resistance of rice seed tissues depending on their internal structure, i.e., cell walls, water content, and other physiological factors.

The electrical resistance of rice seed tissues provides information about their vital state, while the resistance of healthy and damaged tissues differs significantly [7, 8].

$$Z(\omega) = \frac{R+1}{j\omega L}, \qquad (5)$$

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where Z(ω) – complex resistance. Om;
R – membrane resistance, Om;
C – membrane capacity, F;
ω – 2πf – angular frequency, Hz;
j – imaginary unity, $j = \sqrt{-1}$.

The complex resistance is directly proportional to the membrane resistance and inversely proportional to its angular frequency and capacitance [6].

$$\varepsilon = \frac{C\ \delta}{\varepsilon_0\ A}, \qquad (6)$$

where δ – distance between plates, m;
A – plate surface, m^2.

As can be seen from expression (6), the dielectric permittivity of rice seeds is directly proportional to the membrane capacity and the distance between the plates, and inversely proportional to the surface area of the plates.

Using these expressions, it is possible to evaluate the dielectric properties of fluids or membranes between the cells of rice seeds.

Dielectric permittivity is strongly influenced by temperature, humidity, fluid content, intracellular ionic content, and other similar factors [9].

Tangent of dielectric loss [6]

$$\sigma = \frac{\ell}{\rho}, \qquad (7)$$

This coefficient indicates how the tissues of rice seeds absorb electromagnetic waves [10].

Theoretical studies on UV treatment of various diseases and pests in the soil have shown that it damages the DNA structure of pests, disrupts the process of mutation and development, stops their reproduction, and leads to a decrease in their population.

Results. According to the proposed technology, after UVB treatment of the soil and rice seeds, plastic cassettes with rice seeds are stored for one month in a room with sufficient sunlight for germination, and the germinated rice seedlings are treated with UVB 4 times.

Figure 2 shows a schematic diagram of UV treatment of shoots sprouted from rice seeds treated with EFS and UV.



Figure 2: Schematic diagram of UVA treatment for rice seedlings.

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Simultaneous treatment of rice seedlings with UV radiation at a wavelength of 253.7+300 nm shows that the influence process at this scale wavelength occurs in parallel and independently of each other. As a result, a photon process occurs, and the biological object does not undergo a mutation process [11].

Treating rice seedlings with UV radiation does not have a negative effect on them, but causes the seedlings to shudder, and as a result, the progression and renewal of all processes in the cells intensify.

Energy devices for UV treatment of rice seedlings consist of lamps with a power of 30, 60, 90 W and a wavelength of 253.7 + 300 nm. It is possible to change the position of the lamps or use different lamps at the same time to treat rice seedlings at different wavelengths.

The main function of UV treatment is to deliver a specified amount of radiation energy to the receiving bio-object [12]

$$Q = \int_s \int_t E(\tau,\alpha)\,ds\,d\tau\,d\alpha, \qquad (8)$$

where E – irradiation, W/m^2;

τ – radiation time, s;

α – radiation direction, °;

S – radiation field, m^2.

In irradiation installations, the initial calculation parameters E are either predetermined or determined by the irradiation dose H, or they are derived by special calculation.

$$E = \frac{H}{S}, \qquad (9)$$

where H – irradiation dose, J/m^2.

When

$$H = P\,\tau, \qquad (10)$$

taking into account that expression (10) takes the following form:

$$E = \frac{P\,\tau}{S}, \qquad (11)$$

where P – lamp power, W.

For example, if rice seedlings are treated with a 60 W lamp for 22 seconds, its surface area is 0.18 m^2 equals

$$E = \frac{60\ \ 22}{0{,}18} = 7{,}33\ \ 10^3\,J/m^2$$

Similarly, the irradiance values can be found depending on the cultivation surface of rice seedlings treated at different times with 30 and 90 W lamps.

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Consequently, the irradiation value can be found by knowing the power of the lamps for UV treatment of rice seedlings, the treatment time, and the surface area to be treated.

Conclusion. As a result of theoretical research, it was established that the electrophysical properties of rice seeds and sprouts change depending on the functional state of the cell membrane, ion exchange, and external physical factors. Indicators such as membrane potential, electrical resistance, dielectric permittivity, and complex resistance formed in rice seed cells serve as important criteria for assessing the physiological state of the seeds. Theoretical analyses have shown that under the influence of ultraviolet radiation (UVR), physiological processes intensify as a result of increasing the ionic permeability of cell membranes, changes in membrane capacity, and bioelectrical activity. Furthermore, treatment with UVB radiation and electroactivated water (EAW) had a positive effect on the germination of rice seeds and the growth and development of seedlings.

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