

# Ways to increase the internal energy of seeds

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**Abstract.** The article discusses the problem of creating valuable source material for breeding new varieties. Therefore, the authors consider it necessary to develop new methods to induce aberrant or recombinant variability in plants using their own hidden seed reserves. It is proposed to treat wet seeds with physical factors that mobilize forces and release energy reserves of the seeds to increase their germination, seedling growth, productivity and yield of future agricultural products. The article examines the possibility of stimulating and increasing crop yields by controlling the number of chromosomal aberrations under electrophysical influence on their seeds. To increase the water content of seeds prior to irradiation, the authors use a sinusoidal electric current. In order to increase the yield of chromosomal aberrations in the process of laser irradiation of seeds, it is necessary to carry out a preliminary water-thermal treatment (WTT) with alternating electric current (*I*). The authors present the research on the effect of electrophysical treatment methods on seed material, which includes the study of electrophysical properties of seeds, identification of doses, type and nature of effects that cause stimulation of growth and development of their seedlings.

## 1 Introduction

The Food Security Doctrine envisages achieving 75% self-sufficiency in seeds of major crops. About five million tons of seed should be of Russian origin. This is a huge volume and offers excellent prospects for the development of domestic breeding and seed production. Scientists offer methods to improve the pre-sowing treatment of seed material by various physical factors in order to increase yields and improve the technological qualities of grain and other plant products.

One of the most important measures is to increase the yield of these crops by all possible improvements in seed production and quality of seed material, increasing the field germination of seeds.

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## 2 Materials and methods

Not all wavelengths are used for seed stimulation, but mainly electromagnetic fields in the radio wave and optical range. As electromagnetic waves propagate through different media, they are reflected, refracted, scattered, absorbed, diffracted and interfered with [1]. In addition, the speed of propagation of electromagnetic waves is reduced compared to the medium of air, and therefore the wavelength is also reduced.

The intensity of electromagnetic radiation propagating through tissue decreases exponentially with distance (Bouguer's law). The main contributor to the decrease in the intensity of electromagnetic radiation is the absorption of electromagnetic energy in tissue. A significant proportion of the electromagnetic energy is accumulated in systems of charged particles or induces their motion.

Due to the small amount of intercellular fluid and the presence of membrane cells, which essentially limit the mobility of the ions contained in it, the specific electrical conductivity of tissues is much lower than that of their constituent media. Its highest values (0.6 to 2.0  $\text{cm}\cdot\text{m}^{-1}$ ) are found in liquid media. On the contrary, the specific electrical conductivity of connective tissue is much lower than  $10^{-3}$  to  $10^{-6}$   $\text{cm}\cdot\text{m}^{-1}$  [2].

At an EMF frequency of  $1\cdot 10^4$  Hz, the dielectric permittivity is due to cell polarization. This is a double electrical layer formed near the membrane surface [3]. One part is formed by negative charges of hydroxyl and carboxyl groups of membrane glycoproteins, and the second part is formed by mobile positive charges (counterions) electrolytically connected to them. When an external EMF is applied, the latter are displaced along the membrane surface and entrain the water layer near the cell surface. This phenomenon determines the macroscopic surface polarization of the cells [2].

Under the action of EMF of radiofrequency range in various tissues there is a directed movement of charged particles of ions, as well as redistribution of electric charges and formation of volume dipole moment (polarization of tissues). The ordered and directed movement of ions in tissues creates a conduction current in them [4]. Individual processes of frequency-dependent polarization of vibrational displacement of water dipoles in the external EMF form a displacement current.

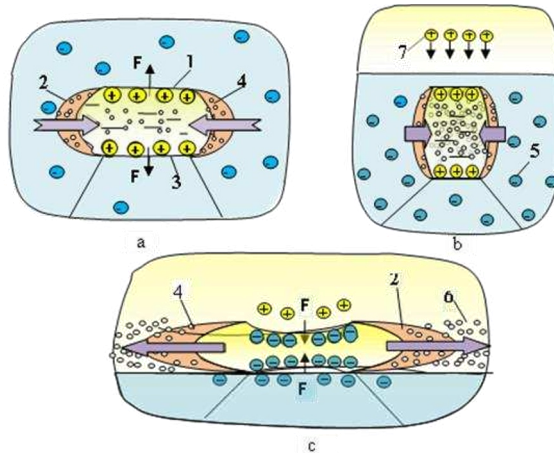
The metabolism in seed cells can be represented in the form of three stages: electromagnetic, when under the influence of mutual electric and magnetic forces associations of ionized molecules and atoms of different substances are formed; electrochemical, when in this association oxidation and reduction processes take place, i.e. electrochemical interaction; electromechanical, when under the influence of electrostatic forces neutral waste products of this interaction are thrown out of the association. Gravity also plays a role in each of these three stages. The electromechanical cleaning movements of the cells, in which the first two stages of metabolism have already taken place and the residues of the electrochemical reactions have to be expelled, should be rhythmic like a relaxation generator. Let us consider one of the models of electromagnetic relaxation.

The cell (Figure 1) has a shell made up of areas with different electrical properties (e.g. areas 1 and 3) that can accept charge on the outer surface and thus provide an opposite charge on the inner surface.

The shell is made up of mutually mobile elements, and over time they will line up in a certain order, determined by the Earth's electric field: the bottom and top of the shell will carry a greater proportion of charges of opposite sign. The belt will have charged water ions – a looser, more porous consistency (areas 2 and 4) (like the Earth, which has a minus sign).

If the cells lie on the surface and are periodically rinsed with water, the entire outer surface of the shell will have a minus sign and the inner surface will have a plus sign when immersed in water. Under the action of electrostatic forces, the cell begins to expand,

drawing in water saturated with ions of organic matter 5, a kind of nutrient broth with appropriate charged components. When the water leaves the cell, it is under the influence of the settling water vapour 7, which carries positive charges and is compressed by the electrostatic forces  $F$  of the charges, more than the lateral belt, which does not carry any charges.



1, 2, 3, 4 – cell membranes; 2, 4 – porous cells; 5 – water saturated with ions of organic materials; 6 – neutral wastes; 7 – positively charged ions

**Fig. 1.** Electromagnetic relaxation model of an organic cell.

Area 1 is positively charged from the outside and negatively charged from the inside. The cell shrinks under the action of electrostatic forces and releases waste 6 into the environment, which, having lost its charge through electrostatic interaction within the cell, becomes neutral and lands on walls 2 and 4 (Figure 1 b and c). This completes the metabolic cycle. As the water vapor continues to settle, it positively charges the surface on which the cell is located. The entire outer surface of the cell will now carry a plus sign and the inner surface a minus sign. As the cell expands, it draws in carbon dioxide ions, water vapor and parts of materials in heavy ions [5].

Seeds are colloidal capillary porous bodies [6]. When moistened, they swell and absorb moisture through a semi-permeable shell, and osmotic binding of moisture to matter occurs due to internal osmotic pressure. If the fluid surrounding the seed has a temperature higher than that of the seed, the movement of moisture has a significant effect on the movement of heat. These two simultaneous processes influence each other and cannot be separated.

The same can be observed when seeds are periodically wetted with water. The seed is made up of many similar cells which, when periodically wetted, improve metabolism and also wash out various substances that affect the growth characteristics of the seedlings.

Since the seed cells contain various types of water-soluble proteins, the heat threshold of coagulation of which is between 40°C and 42°C [7], it is necessary to reduce the temperature of hot water to 40°C and cold water to 20°C, because wetting the seeds at a relatively low temperature of 15°C-18°C leads to a sharp reduction in the number of surviving seeds and slow growth of the resulting seedlings [2], then we will get the optimum temperature of their treatment.

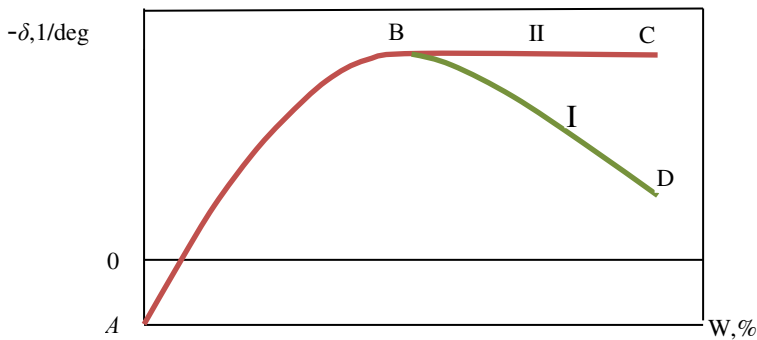
On the basis of scientific and experimental data, the author developed a method of seed treatment to increase the yield of chromosomal aberrations and to improve the stimulation processes of seedling development, which involves pre-treatment of seeds with water of

contrasting temperatures of 40°C and 20°C, i.e. their water-thermal treatment followed by laser irradiation [8].

The temperature of the centre of the seed during WTT with contrasting water temperatures of 40°C and 20°C approaches almost the temperature of the water washing the seed in 30 seconds. The rate at which the internal temperature of the seed approaches the ambient temperature increases with increasing treatment time, i.e. with increasing number of treatment cycles.

In water-thermal treatment, seeds are exposed to two contrasting temperatures in water for a period of time, during which they are heated and cooled. The heat exchange between the seed surface and the environment, i.e. the transfer of moisture, takes place by diffusion. The law governing this heat exchange is rather complicated and, to simplify the problem, it can be taken in the form of the Newton-Richman law. The optimum water temperature for treating seeds to improve germination is 37°C. It is therefore necessary to choose the duration of the treatment of the seeds with water of contrasting temperatures so that the seeds are at this optimum temperature for the maximum time.

The coefficient  $\delta^1$  varies for most materials according to curve I or curve II (Figure 2). This nature of the dependence of the coefficient of thermal conductivity of moisture  $\delta^1$  on the wet material can be explained by the fact that, at low values of moisture content, the movement of moisture is initially mainly in the form of vapour (thermodiffusion of adsorbed moisture) and then mainly in the form of liquid (thermal conduction of capillary moisture).



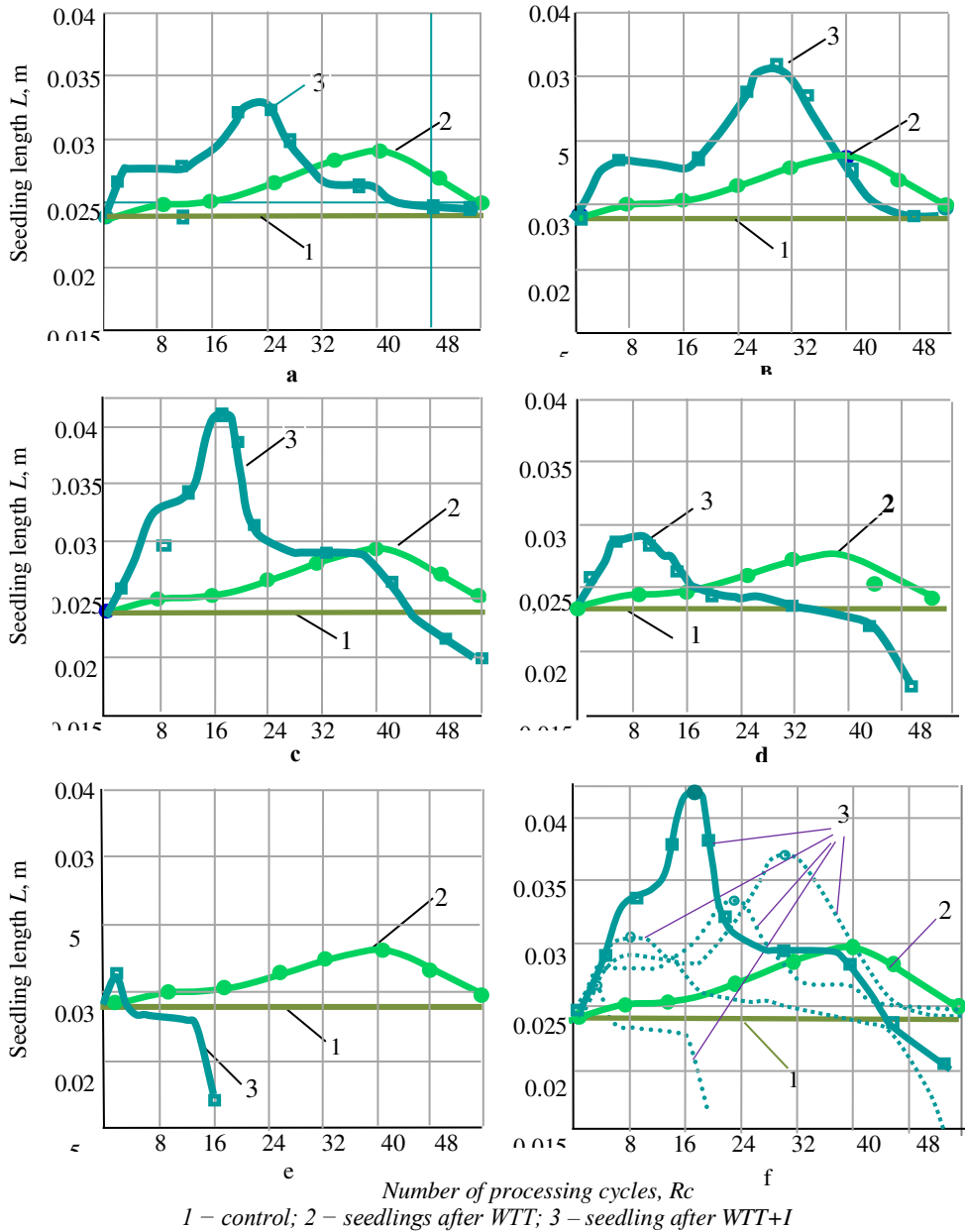
**Fig. 2.** Dependence between thermal moisture conductivity coefficient and material moisture content.

The extreme point gives the approximate boundary between adsorption bound moisture and capillary moisture, so in the case of thermal diffusion of liquid and adsorption bound moisture, the coefficient  $\delta^1$  should increase with material moisture [9].

The difference between curves I and II is that in the first case the thermal moisture diffusion caused by the trapped air is dominant in this moisture area, whereas in the second case it is not significant. The trapped air occurs when there is a temperature difference between the temperature of the fluid surrounding the body. In heated areas of a porous body, the trapped air expands and pushes the fluid into colder areas [2].

When the maximum moisture content is reached, the coefficient is zero because in this state all the pores are filled with liquid and there is no trapped air. As the temperature of the liquid surrounding the body increases, the maximum of the curve  $\delta^1 = f(u)$  shifts towards lower moisture content.

All seeds have a single mechanism of energy reception and the receiver of this energy are water molecules, which contribute to increase both the internal energy of seeds and the energy absorbed by them under the influence of physical factors, causing stimulation processes of plant development (Figure 3).



**Fig. 3.** Dependence of the seedling length of seeds subjected to WTT on the value of alternating electric current: a) current – 1A; b) current – 2A; c) current – 3A; d) current – 4A; e) current – 5A; f) – total plot of seedling length curves from WTT+I.

Consequently, the more water the seeds absorb, the more energy they will be able to absorb during subsequent irradiation, because the water-filled seed cells during irradiation increase their radiosensitivity, and the stimulation of seedling development in these seeds is much higher, so there is a positive correlation between various damages in cells – gene mutations, chromosome aberrations, etc. and stimulation of plant seedling development.

In order to accelerate the process of moisture absorption in seeds and to improve metabolic processes in seed cells, the authors used another stimulating physical factor - sinusoidal electric current.

Since water molecules are dipoles, they are accelerated under the effect of the potential difference and pumped into the seed cells from both sides through the pores of the membrane (pore diameter – 0.4 nm, water molecule diameter – 0.24 nm). The size of the capillaries of the seed cells also increases, the distance between them increases, and as a result of electroosmotic forces there is an additional pumping of water into these free spaces between molecules, which contributes to pushing the water deep into the seeds and accelerating the process of their wetting.

When periodically exposed to contrasting water temperatures, seeds, like all physical bodies, will expand when heated and contract when cooled. The size of the capillaries in the seed cells also increases, the distance between them increases and, as a result of electroosmotic forces, there is an additional pumping of water into these free spaces between the molecules, which helps to push the water deep into the seeds and accelerate the process of their wetting. The electrical resistance of the seed then decreases as the air-filled space inside the seed, which is the dielectric in dry seeds, is reduced and current flows through the cells of the seed embryos.

In the presence of potential differences across the electrodes and temperature gradients, ion and water exchange takes place in the seed cells. Once inside the seed cells and subjected to ionization by directed electrons, water molecules are broken down by the passage of alternating electric current [10]:



The energy required to ionise one molecule of water is  $2 \cdot 10^{-18}$ J. The secondary electrons produced by this process then appear.

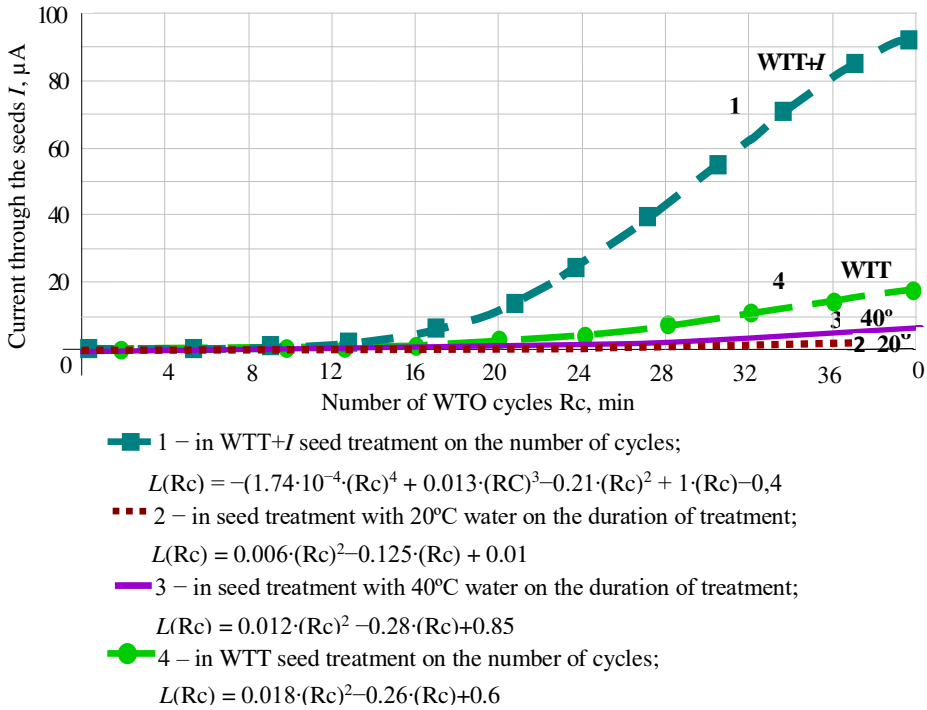
The products of the electrolysis of water are ions:  $\text{OH}^-$ ,  $\text{H}^+$  and  $\text{H}_2\text{O}^+$ ; atoms and molecules: H,  $\text{H}_2$ ,  $\text{H}_2\text{O}_2$ ; radicals:  $\text{H}^-$ ,  $\text{OH}^-$ ,  $\text{e}^-$ . They serve as mediators of vital metabolic processes in seed cells, such as respiration, metabolism of trace elements, photosynthesis, energy storage, etc. Water is an additional source of adenosine triphosphate (ATP) formation (cell energy stations) [11].

As a result, the seed cells are saturated with the necessary ions and water. Their electrical resistance drops and the seeds begin to pass significant alternating electric currents through themselves. These currents stimulate the vital processes of the seeds, thus improving their economically valuable properties.

On the basis of the studied material, the authors developed a method and a device for complex treatment of seeds with water of different temperatures and alternating electric current in order to determine the optimal modes of seed treatment to maximise the effect of stimulation of seedling growth and development of future plants [12].

### 3 Results

In order to experimentally test this method, five groups of cucumber seeds were treated with water at the same contrasting temperatures of 20°C and 40°C, with each group of seeds exposed to a different treatment current: 1A, 2A, 3A, 4A, 5A. Untreated dry seeds were used as a control (Figure 4). They were placed between electrodes in a tank of water through which an alternating current was passed.



**Fig. 4.** Dependence of current flowing through seeds after different methods and time of their treatment.

When the seeds were exposed to water at different temperatures in combination with alternating current, the length of the seedlings in the different groups was different. It increased with increasing treatment current up to a value of 3A and then decreased with further increase in treatment current values compared to the untreated control seeds.

Thanks to these experiments, the authors determined the optimal stimulation modes of water-thermal treatment together with alternating electric currents for cucumber seeds of the variety “Vodoley” and plotted the curves of dependence of seedling length on the value of alternating electric current of treatment and on its duration. Figure 3 shows that the maximum effect of seedling growth stimulation is observed at water-thermal treatment of seeds together with alternating electric current of 3A. The experiment was carried out in four repetitions. Thus, after comparing the seedling lengths of all five experimental variants, the authors selected the mode with the maximum seedling length and thus found the optimal treatment mode for cucumber seeds of the variety “Vodoley”.

Seeds treated in the selected mode of stimulation had an increased number of chromosomal aberrations, which led to an increase in germination, accelerated development of seedlings grown from these seeds, which further led to an increase in their yield. Experiments with other types of seeds showed that for each type of seed it is possible to experimentally select the optimum mode of complex treatment by the proposed method.

Electric current causes physiochemical effects in seeds, such as electrolysis, polarisation and electroosmosis. Moisture contributes to its strengthening, as it becomes a good conductor of electric current and at maximum saturation of seeds contributes to its transmission of significant values.

On the basis of the above, experiments were carried out to compare the values of electric current  $I$  passing through seeds of length  $\ell$  and area  $S$  after different methods of their treatment for the same number of cycles  $Rc$ , in order to determine the mode in which

the current of maximum value passes through the seeds, bringing with it the maximum electric energy used by the seeds during their germination.

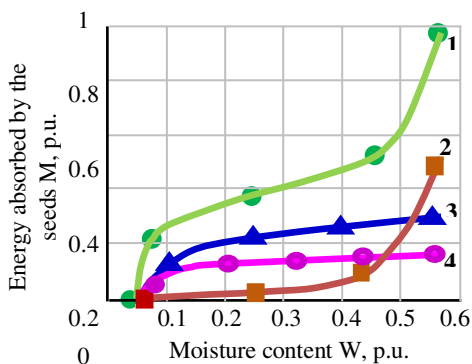
The seeds were subjected to WTO+ $I$ , i.e. they were placed between the condenser liners and alternately wetted with water of contrasting temperatures of 20°C and 40°C with simultaneous passage of alternating current. The control for this method of seed treatment was the method of water-thermal treatment without the application of alternating current.

Two more groups of seeds were included in the experiment, one treated with 40°C water only and the other with 20°C water. The water temperatures of 20°C and 40°C were chosen on the basis of the effective biological activity of plant cell proteins. During the experiment, the electrical resistance and weight of the seeds were measured, then their moisture content and the current that would flow through the seeds if their electrical resistance changed were determined.

The most effective method was to treat the seeds together with water at different temperatures and alternating current. In this case, electroosmotic forces cause the seeds to wet more quickly and the electrical resistance to decrease. The next most effective method is water-thermal treatment of seeds, followed by treatment of seeds with 40°C water and finally treatment of seeds with 20°C water. According to the results of the experiment, curves of the dependence of the sinusoidal electric current change on the number of seed wetting cycles were plotted (Figure 4).

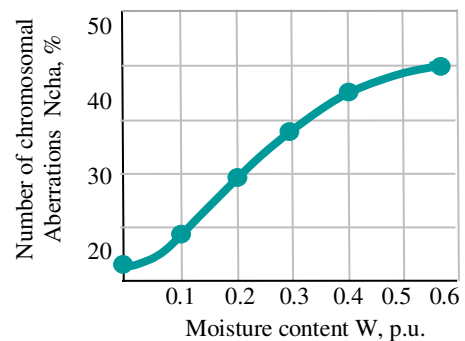
## 4 Discussion

The complex water-thermal treatment of seeds with water of contrasting temperatures (20°C and 40°C) together with alternating electric current and subsequent laser irradiation resulted in the maximum stimulation of seedling growth and the maximum yield of aberrations in comparison with other methods of seed treatment. The dependence of the energy absorbed by the seeds on the amount of moisture and the yield of chromosomal aberrations in them was calculated and plotted (Figures 5 and 6). The more moisture in the seeds, the more energy they absorb, which allows an increase in the output of chromosomal aberrations and, as a result, their physical, biological and, ultimately, morphological parameters are modified, contributing to an increase in yield.



**Fig. 5.** Dependence of the amount of energy absorbed by seeds on the moisture content.

- 1 – total energy of seed treatment;
- 2 – current treatment of seeds;
- 3 – WTO+laser; 4 - WTO of seeds.



**Fig. 6.** Dependence of changes in chromosomal aberrations of cucumber seeds of the variety "Vodoley" on the moisture content and laser irradiation.

## 5 Conclusions

Moisture transfer in capillary-porous colloidal bodies, i.e. seeds, is improved under the influence of alternating electric current, which leads to an increase in the saturation of seeds with water and, consequently, to a decrease in their electrical resistance and an increase in the value of the current passing through them, which improves the development stimulation and seedling growth of the seeds.

The proposed methods can be used in breeding centers for the development of new varieties of agricultural crops, as well as in vegetable and cereal farms for the pre-sowing stimulation of seeds.

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