

ANALYSIS OF ELECTROTECHNOLOGICAL TREATMENT METHODS FOR
BEETROOT SEEDS**Kamoliddin Muxammadumarov Faxriddin o'g'li**Researcher at the Department of Energy Engineering,
Namangan State Technical University<https://doi.org/10.5281/zenodo.23254394>

Abstract. The paper analyzes the main electrotechnological methods of pre-sowing treatment of beetroot (*Beta vulgaris* L.) seeds: electric field, low-frequency electromagnetic field, ultraviolet and laser irradiation, cold plasma, and electrochemically activated water. The methods are compared by their influence on seed germination, energy consumption, and feasibility of technological implementation. As a result of the analysis, the most promising methods are identified, and issues that require attention when introducing them into agricultural production are described.

Keywords: beetroot, seeds, electrotechnology, electric field, cold plasma, laser irradiation, ultraviolet irradiation, germination, pre-sowing treatment.

Introduction. Beetroot is an important vegetable crop in Uzbekistan, ensuring a year-round supply of vegetables for the population. Its yield largely depends on seed quality and on emergence indicators in the field. Beet seed is a multi-germ fruit cluster (glomerule) containing several embryos. Its thick, hard pericarp slows down the penetration of water and air, and it also contains substances that inhibit growth. For this reason, the seed may show uneven and low field germination.

Pre-sowing chemical treatment has a negative impact on the environment and on product quality. Electrotechnological methods are therefore considered an alternative direction, since they are environmentally friendly, easy to dose, and suitable for automation. In addition, they can be integrated into existing seed preparation lines without fundamental changes to the technological process.

The aim of the research is to analyze the methods of electrotechnological treatment of beetroot seeds and to compare their effectiveness.

Research Methods. A systematic analysis of the scientific literature was carried out. The methods were compared according to the following criteria: biological efficiency (germination energy, germination capacity, early seedling growth), specific energy consumption, treatment uniformity, equipment complexity, environmental safety, and feasibility of introduction into production.

Main Part. A brief description of the analyzed methods is given below.

Electric field and corona discharge. The seeds are treated between high-voltage electrodes. The field increases the permeability of cell membranes and enzyme activity, which accelerates water uptake. The method is simple and has low energy consumption, but the result depends strongly on field strength and exposure time. If these parameters are chosen incorrectly, seedling growth may slow down.

Low-frequency electromagnetic field. The field activates biochemical processes inside the seed. The method does not damage the seed; however, its effect is sensitive to cultivar and moisture content, so the optimal mode has to be determined experimentally.

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Ultraviolet irradiation. At low doses, it disinfects the seed surface and stimulates growth. An excessive dose damages the embryo. The thick seed coat of beet limits the penetration of light into the seed, so the method is mainly suitable for surface treatment.

Laser irradiation (e.g., He-Ne laser). Monochromatic light activates physiological processes through photoreceptors. The advantage of the method is dosing accuracy; its drawbacks are the high cost of the equipment and the difficulty of uniformly treating large volumes of seed.

Cold (non-thermal) plasma. Devices such as dielectric barrier discharge increase the hydrophilicity of the seed coat, reduce surface microorganisms, and improve water uptake. This is especially important for seeds with a thick pericarp. Improved germination of various crops has been reported in the literature, although the result depends on the mode and cultivar. The method is modern and promising, but standardized modes are still insufficient for industrial implementation.

Electrochemically activated water (anolyte/catholyte). Short-term soaking of seeds can provide disinfection and faster germination. The method is easily integrated into the existing soaking process and reduces the consumption of chemical protectants.

Comparative assessment (qualitative).

Method	Efficiency	Energy consumption	Treatment uniformity	Ease of implementation
Electric field / corona	moderate	low	moderate	high
Low-frequency EM field	moderate	low	high	high
Ultraviolet	low–moderate	low	moderate	high
Laser	moderate–high	moderate	low	low
Cold plasma	high	moderate	moderate	moderate
Activated water	moderate	low	high	high

Table 1.

Comparison of electrotechnological methods for beetroot seeds

The analysis showed that, since the main problem of beet seed is its thick pericarp, methods that improve water and gas exchange (cold plasma, activated water) are preferable. Simple and inexpensive methods (electric field, electromagnetic field) are convenient for small farms, where complex equipment and skilled maintenance are not always available.

It should also be noted that the effect of any physical factor has a dose-dependent character: low doses stimulate, while excessive doses inhibit seed development. Therefore, a universal mode for all cultivars cannot be recommended, and each method requires preliminary experiments with local cultivars under local conditions. For practical introduction, it is also necessary to ensure uniform treatment of the whole seed batch, which is most easily achieved with continuous-flow devices that move the seeds through the treatment zone at a controlled speed.

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Discussion. Comparison of the methods shows that no single technique is best by all criteria. Laser irradiation offers precise dosing but is limited by equipment cost and by the difficulty of treating large seed batches uniformly. Ultraviolet irradiation is cheap and effective against surface microflora, but it is restricted by the low penetration of light through the thick pericarp. Electric and low-frequency electromagnetic fields are technically simple, yet their results are highly sensitive to the chosen parameters.

Cold plasma and activated water act directly on the main obstacle, the seed coat and its water-impermeable properties, which explains why they are rated as the most promising. At the same time, their introduction requires standardized treatment modes, control of seed moisture before treatment, and verification of the effect on the seed's storage stability after treatment. These questions have not yet been sufficiently studied for beetroot specifically and should be addressed in experimental work.

From the practical point of view, the choice of method should consider the scale of the farm. Large seed-producing enterprises can justify the cost of plasma or combined installations, whereas small and medium farms may prefer activated-water soaking or electric-field treatment, which need less investment. Environmental and occupational safety is an additional advantage of all the considered methods, since they do not leave chemical residues on the seed or in the soil, provided that standard electrical safety requirements are observed.

Conclusion

Electrotechnological methods can serve as an environmentally friendly alternative to chemical treatment of beetroot seeds.

The most promising methods are cold plasma and electrochemically activated water, which reduce the barrier properties of the pericarp and disinfect the seed.

The optimal mode of each method (field strength, dose, exposure) depends on the cultivar and seed moisture content; therefore, experiments with local cultivars are necessary.

Further research should focus on reducing energy consumption, ensuring treatment uniformity, and developing equipment for production use.

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