УДК 004.9

DEVELOPMENT OF A BIOTECHNICAL SYSTEM FOR PRE-SOWING PULSED LASER IRRADIATION OF SUNFLOWER SEEDS

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Relevance of Research. Sustainable agriculture demands innovative approaches to maximize crop yield while minimizing environmental impact, making the development of biotechnical systems a critical focus. Pre-sowing treatments are essential in ensuring seed quality, germination rates, and crop productivity, especially for high-value crops like sunflower. Traditionally, chemical stimulants have been used to enhance seed performance, but these can introduce residual chemicals into soil and water systems, leading to environmental degradation and affecting long-term soil health [1]. Pulsed laser irradiation offers a non-invasive, environmentally friendly alternative that utilizes light to stimulate physiological processes within the seed, thereby improving germination without the use of chemicals.

The effectiveness of laser irradiation lies in its ability to activate phytochromes, the light-sensitive molecules that regulate plant growth, especially during the critical germination phase. This process triggers a cascade of growth-promoting reactions that enhance both the speed and quality of germination. However, the ideal parameters for effective pulsed laser treatment—including pulse frequency, energy density, and exposure timing—are not universally established and require precise calibration. By identifying optimal irradiation conditions, this research aims to provide an energy-efficient, reproducible, and safe method for pre-sowing seed treatment. Such an approach holds particular promise for sunflower crops, where quality seeds are essential for high yields and resource-efficient production. Ultimately, this research contributes to sustainable agriculture by developing eco-friendly alternatives to chemical seed treatments, promoting both yield and environmental stewardship [2].

Purpose of Research. The main purpose of this research is to determine the optimal parameters for pulsed laser irradiation that enhance the sowing qualities of sunflower seeds. By identifying and refining the specific irradiation settings, this study aims to improve germination rates and seed vigor while reducing the energy inputs required for effective pre-sowing treatments. Another key objective is to design and develop a biotechnical system that can precisely control these parameters in real-time, allowing for consistent, repeatable results across different batches of seeds.

The biotechnical system is intended to be versatile, cost-effective, and adaptable for a range of agricultural scales, from large-scale commercial farms to small-scale operations [3]. This adaptability is crucial in addressing the needs of diverse agricultural setups, enabling a wide range of producers to access advanced seed treatment technology without prohibitive costs. Furthermore, by integrating this system with existing agricultural practices, the study seeks to facilitate the use of sustainable pre-sowing treatments, reducing reliance on chemical stimulants and their associated environmental risks.

Basic Research Materials. The research employed artificially aged sunflower seeds to simulate real-world challenges of reduced seed quality. Artificial aging is a technique used to replicate degradation, mimicking conditions where seeds experience decreased vigor and germination rates due to prolonged storage or suboptimal conditions. By simulating these effects, the experiment aimed to test the effectiveness of pulsed laser irradiation in restoring or enhancing seed quality, making it feasible for use with compromised seed lots [4-5].

A laboratory installation of the type of "spot-line" fiber-optic converter with an interrupting device, such as an obturator, with a constant speed of rotation is used. The relative movement of the transducer and the processed material was carried out in one direction, which greatly simplified the design and increased its reliability. The basis of this device is an Atmel type AT90S2313 microcontroller.

A full factorial experiment was conducted to assess the dependence of the sowing qualities of the seeds (PSYAN) on the parameters of pulsed pre-sowing irradiation.

Variation factors are selected:

X_1- the number of days from irradiation to the beginning of determination of sowing qualities of seeds [6], days; X_2- number of pulses, pcs. ;X_3- energy density, mW/cm^2 (Table 1).

Table 1. Factor variation levels

Factor	Unit	Levels of factor variation				Sign
		-1	0	+1	Δ_i	
The number of days from the exposure to the beginning of the determination of PYAN	days	3	9	15	6	X1
Number of pulses	thousand pcs.	2	5	8	3	X2
Energy density	mW/cm^2	0.5	3.25	6	2.75	X3

A plan matrix was constructed for the obtained regression equation (Fig. 9)

$$y_i = B_0 + B_1 z_1 + B_2 z_2 + B_3 z_3 + B_{12} z_1 z_2 + B_{13} z_1 z_3 + B_{23} z_2 z_3 + B_{11} {z_1}^2 + B_{22} {z_2}^2 + B_{33} {z_3}^2$$

The biotechnical system developed for this research integrates a fiber-optic converter connected to a stepper motor controlled by a microprocessor. The motor, operating at a constant speed, allows for uniform laser application across each batch of seeds. This precision setup ensures that seeds receive consistent irradiation, maintaining quality without the risk of overexposure [7]. The system is adaptable for various agricultural scales, from laboratory use to practical field applications, and allows for real-time adjustment of parameters based on seed type and initial quality.

Conclusion. This study demonstrates that optimized pulsed laser irradiation significantly enhances sunflower seed germination and quality, providing a sustainable alternative to chemical treatments. The identified optimal parameters—1931 pulses, 3.25 mW/cm^2 energy density, and 8.5 days pre-sowing—resulted in improved seed vitality and comparable quality to higher-grade seeds. The biotechnical system developed ensures precise, reproducible irradiation, adaptable for various agricultural scales. By reducing chemical dependency and supporting efficient, eco-friendly farming practices, this system represents a practical solution to enhance crop productivity and resilience, contributing positively to sustainable agricultural development.

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