Optimization and Simulation of the Process Electro Impulse Treatment of Plants

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***Abstract:-** The questions of optimization of parameters and simulation of the process of electro impulse processing of the root system of tomatoes and cucumbers are considered; the results of computational experiment with the use of polynomial models of the optimized object are given.*

***Keywords:** electrical impulse, root system, tomatoes, cucumbers, mathematical models, functional limitations, parametric optimization, simulation, Monte Carlo method, computational experiment..*

I. INTRODUCTION

One of the most pressing problems in crop production is the control of parasites that affect the stems and root systems of plants. One type of such parasites is nematodes, which affect almost all types of crops and cause significant damage by devouring crops [1].

On the basis of many years of research in the Tashkent Institute of Irrigation and Mechanization of Agriculture developed a new technology to combat root nematode and electro-pulse unit for its implementation [2]. The proposed technology differs in the fact that it is economical, environmentally safe and efficient. Application of this technique does not affect the cost of the harvest and, most importantly, has no dangerous consequences. It is used in summer after the harvest or in autumn tillage.

Below is an illustration of the principle of operation of the electro-pulse plant to combat root nematode.

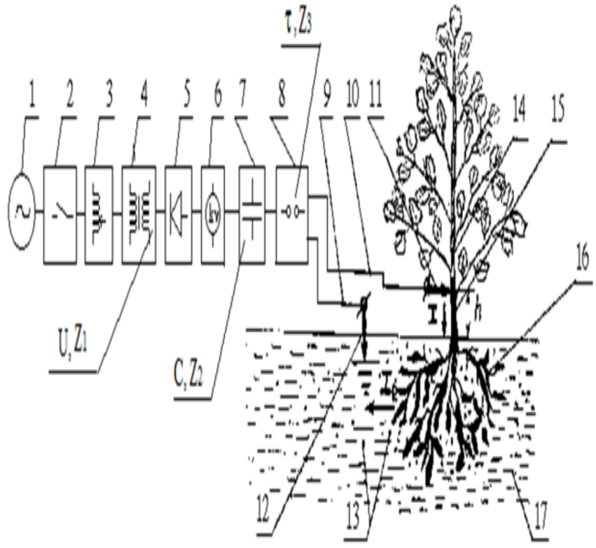

Figure 1 - Structural diagram of installation of electro-pulse treatment of plants

1 - electric power supply; 2 - automatic switch; 3 - laboratory autotransformer; 4 - step-up transformer; 5 - high-voltage vent diode; 6 - high-voltage voltmeter; 7 - capacitors; 8 - pulse electrodes; 9-10 - high-voltage cable; 11-12 - contact electrode; 13 - parasites; 14 - affected plants; 15 - plant neck height; 16 - plant root infected with nematode; 17 - soil.

On the basis of theoretical and experimental studies on the use of electro impulse discharges to control the carriers of the nematode virus, a mathematical model of the process of electro impulse treatment of plants was developed [3].

The construction of mathematical model of the process of electro impulse treatment of plants was carried out using the method of optimal planning of the experiment [4]. In particular, orthogonal plans of the second order were applied.

RESULTS & DISCUSSIONS

Finally, after elimination of insignificant coefficients of the regression equation, two mathematical models for tomatoes and cucumbers were obtained, which in natural scale have the following form:

- for tomatoes

$$\hat{y}_1 = 15.52856212 - 0.00141989 z_1 - 100.0153 z_2 - 0.0048896 z_3 + 0.00000015298 z_1^2 + \\ + 291.752499 z_2^2 + 0.0000017107 z_3^2; \quad (1)$$

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- for cucumbers

$$\hat{y}_2 = 15.059 - 0.0013127z_1 - 91.98046z_2 - 0.00617z_3 + 0.0000001412z_1^2 + 279.187z_2^2 + +0.00000228285z_3^2, \quad (2)$$

where z_1 - the electrical voltage at the transformer output; z_2 - the duration of the electrical pulse; z_3 - the capacitance of the capacitor, which are the input parameters to be optimized; $\hat{y}_1, \hat{y}_2$ - the deadening coefficient, which is the output parameter and is used as a criterion of optimality.

The task of optimizing the parameters of the process of treatment of plants by electric discharge is as follows:

$$y(z) \to \min_{z \in \Omega} \quad (3)$$

where

$$\Omega = \left\{ z \in R^n \middle| g(z) \le 0;\ z_{j\min} \le z_j \le z_{j\max};\ j = \overline{1,3} \right\}$$

many acceptable solutions; $z_{j\min} \le z_j \le z_{j\max};\ j = \overline{1,3}$ - direct restrictions on process input parameters; $g(z) \le 0$ - converted functional restrictions on process output parameter.

This requirement to the value of the output parameter is rigid and not always achievable in practice due to various reasons of technical nature. It is often sufficient that only the functional limitations on the output parameter $y \le t$ are fulfilled.

Let's introduce an assessment of the degree of performance of functional limitations $y \le t$, which can be a reserve $f(z) = \left[\left(t - y(z) \right) / \delta - 1 \right] \ge 0$, and rewrite the task (7) as follows:

$$f(z) \to \max_{z \in A} \quad (4)$$

where δ is the allowable range of output parameter values, which is set for practical reasons or determined by the method of statistical tests; A - the set, in which direct restrictions on the variable parameters by means of appropriate replacement, for example $z_j = z_{j\max} + \left(z_{j\min} - z_{j\max} \right) * \sin^2(z_j^{'})$, are converted to functional; $z_j^{'}$ - the value of j-th variable parameter out of the set Ω.

Functionality (4) may not be smooth, which significantly complicates the situation and requires the use of special optimizing procedures, which are highly complex. Let's apply the procedure of smoothing the functionality (4).

It is obvious that $\arg\min\left(f(z) \right) = \arg\max\left[\exp\left(-f(z) \right) \right]$. Therefore, task (4) is rewritten as follows:

$$\max\left[\exp\left(-f(z) \right) \right] \to \min_{z} \quad (5)$$

Having $\varphi(z) \overset{\Delta}{=} \exp\left(-f(z) \right)$ finally adopted the following modified optimality criterion

$$F(z) = \exp\left(-\gamma \cdot f(z) \right) \to \min_{z \in D};\ \gamma = 1, 2, \ldots \quad (6)$$

When solving practical problems on the basis of the modified criterion (6) it is expedient to increase the parameter γ step by step, which will allow, firstly, to avoid the overfilling of the computer's digit grid, and, secondly, to stop the process when obtaining a satisfactory solution in time.

Application in practice of the modified criterion (6) allows us to overcome the problem of "gully" and $A = \left\{ z \in R^n \middle| z_{j\min} \le z_j \le z_{j\max};\ j = \overline{1,3} \right\}$ to obtain a single solution using the simplest algorithms of smooth optimization due to the limitation and closure of the set [5, 6].

The solution of the optimization problem in the statement (6) was made with the use of the obtained mathematical models (1) and (2) by the method of coordinate-release on the computer with Intel® Pentium (R) CPUG4560 3.5 GHz RAM 8GB. The program is made in FreePascal in Lazarus version 1.6.4.

When solving the problem of parametric optimization with the use of mathematical models (1) and (2) the transition to a dimensionless scale was carried out according to the formula $x_i = \dfrac{z_i - z_i^0}{\Delta z_i};\ i = \overline{1,3}$, where $z_i^0 = (z_{i\max} + z_{i\min})/2;\ \Delta z_i = (z_{i\max} - z_{i\min})/2;\ i = \overline{1,3}$ the value t was taken equal to 1.5. The following results were obtained with regard to this restriction

1. formodels (1) $x_1 = -0{,}1996;\ x_2 = 0{,}98;\ x_3 = -0{,}063;\ t = 1{,}5;\ y_1 = 1{,}1$;
2. for models (2) $x_1 = -0{,}3988;\ x_2 = 0{,}96;\ x_3 = -0{,}065;\ t = 1{,}5;\ y_2 = 1{,}4$.

Simulation modeling was carried out by the Monte Carlo method. The purpose of the simulation was to assess the risks of violating the functional limitations at the found optimum point due to possible random variations in the values of the input parameters $z_1,\ z_2,\ z_3$.

The simulation algorithm is shown in Fig. 2. The software implementation of the simulation algorithm was carried out in FreePascal in Lazarus version 1.6.4.

The generation of random numbers in the program implementing the simulation algorithm was carried out in two stages.

At the first stage with the help of random operator two random numbers q_1 and q_2 were generated and with uniform distribution law in the range from 0 to 1.

At the second stage, the transition to random numbers with a normal distribution law was made by the formula

$$x_i = x_{iн} + \delta_i \sqrt{2\ln\left(\frac{1}{q_2}\right)} \sin\left(2\pi q_1\right);\ i = \overline{1,3}$$
,

where $x_{iн}$ is the nominal value of the i-th factor; δ_i - the range of values of the i-th input parameter, chosen for practical reasons in fractions of the nominal value.The obtained values were substituted in the model (1) and (2) as input parameters. A total of 10,000 sets of numbers were generated.

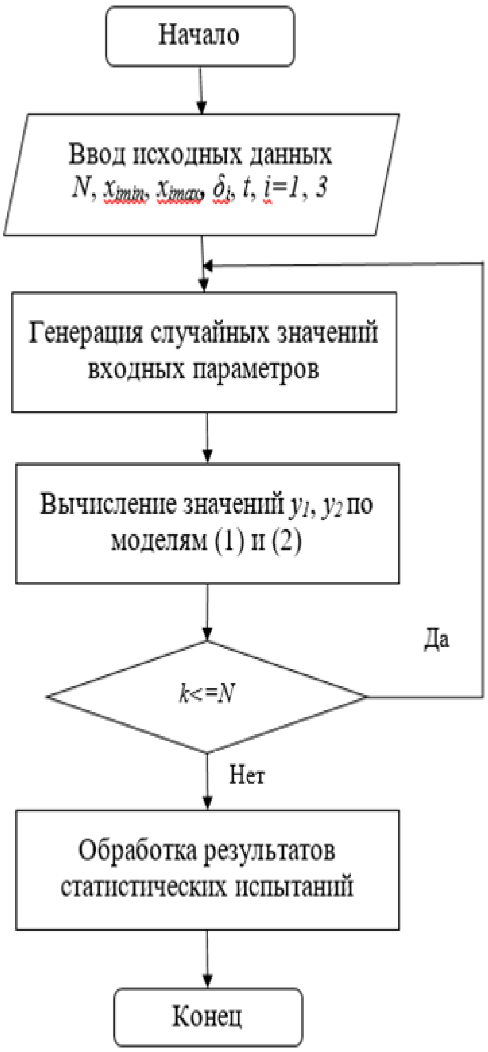

Figure 2 - Block diagram of simulation algorithm

Statistical sums for further evaluation of statistical characteristics of the output parameter were accumulated according to formulas:

$$S_1 = \sum_{k=1}^{N} y_k;\ S_2 = \sum_{k=1}^{N} y_k^2;\ S_{3i} = \sum_{k=1}^{N} y_k \cdot x_{ik};\ i = \overline{1,3};$$

$$S_{1i} = \sum_{k=1}^{N} x_{ik};\ i = \overline{1,3};\ S_{2i} = \sum_{k=1}^{N} x_{ik}^2;\ i = \overline{1,3};$$

$$S_4 = \sum_{k=1}^{N} q_k,$$

where " q_k equals "0" if the functional limits on the output parameter in the k-th test are not fulfilled, and "1" if the functional limits on the output parameter in the k-th test were fulfilled.

Table 1
Simulation results

$z_{1н}$	$z_{2н}$	$z_{3н}$	δ_1	δ_2	δ_3	M_{xi}; $i=\overline{1,3}$	M_y	σ_{xi}; $i=\overline{1,3}$	σ_y	$\lvert r_{yx_i} \rvert$; i	p
Tomatoes											
3001	0,199	1005	0.04	0,04	0,04	3001,29 0,198 1005,257	1,177	64,66 0,004329 21,6848	0,08	0,77505 0,84650 0,58775	1
Cucumbers											
2503	0,198	1003	0.04	0,04	0,04	2053,24 0,197 1003,257	1,5	53,9354 0,0426 21,6416	0.09	0,76362 0,85787 0,57446	1

At processing of results of statistical tests estimations of mathematical expectation $M_i = S_{1i} / N;\ i = \overline{1,3}$ and dispersion $S_i^2 = \left(S_{2i} - N \cdot M_i^2\right) / \left(N - 1\right);\ i = \overline{1,3}$ of input parameters are calculated; estimations of mathematical expectation $M_y = S_1 / N$ and dispersion $S^2 = \left(S_2 - N \cdot M_y^2\right) / \left(N - 1\right)$ of output parameter; coefficients of correlation between pairs of output and input parameters $r_{yx_i} = \dfrac{S_{3i} - N \cdot M_y M_i}{(N-1)\sigma_i \sigma_y};\ i = \overline{1,3}$, and also probability of performance of functional restrictions on output parameter $p = S_4 / N$, where $\sigma_y = \sqrt{S^2}$ - estimations of standard deviation of output parameter; $\sigma_i = \sqrt{S_i^2}$ - estimations of standard deviation of i-th input parameter.

The results obtained in the course of simulation by the models (1) and (2) are summarized in tables t1. From the obtained results it is visible, in the vicinity of the found for tomatoes $z_1 = 3001;\ z_2 = 0.199;\ z_3 = 1005$ and cucumbers $z_1 = 2503;\ z_2 = 0.198;\ z_3 = 1003$ points of optimum functional restrictions on the output parameter are not violated.

CONCLUSION

Therefore, it is possible to consider that the received optimum is steady and corresponding to it values of parameters of process of electro impulse processing of plants can be applied in practice at struggle against wreckers of plants.

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