Study on the effect of electric pulse treatment for disinfestation of vegetables

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Abstract. This paper describes a method of using pulsed discharge to control nematode diseases on tomato and cucumber rhizomes and crops grown in dacha plots. When pulsed discharges are applied to living tissue, certain chemical, physical, and biological processes occur, depending on the pulse energy, pulse discharge current, pulse discharge voltage, pulse discharge exposure time, pulse discharge impact current, and other similar factors. Electric pulses were applied to grafts of nematode-infested vegetables, tomatoes and cucumbers, to measure grafting ability. Crop yields were estimated by the total amount of produce grown on arable land, and the level of yield enhancement was determined by land sedimentation and proper placement of varieties and plant species. Proper selection of modern high-yielding varieties imported from Uzbekistan provides resistance to external adverse effects of nature and diseases. The creation of high-yielding varieties requires the discovery and cultivation of resistant hybrid varieties and the development and introduction of new progressive technological methods of plant cultivation. The objective of this study was to identify the main factors affecting the electric pulse discharge treatment of tomato and cucumber root crops infected with nematodes and their larvae. Various diseases occur in cotton, cereals, melons, vegetable crops, and indoors(greenhouses) on newly established farms in the Republic. Yields are particularly high in vegetable, melon, and greenhouse fields. In recent years, the impact of nematodes on plants has caused severe damage to crop yields. Treating crops with this formulation prevents nematode infestation of leaf veins. The economic damage caused by nematodes to agriculture is enormous. For example, in greenhouse vegetables (cucumbers and tomatoes) this indicator reaches 60% and in potatoes 80%. Therefore, the proposed method is realized in combination with an agrotechnical treatment process that is energy-saving, environmentally safe, and productive.

1. Introduction

Efforts to meet the increasing demands of the expanding human population and global economy for food and energy have resulted in the augmentation of crop yield through the utilization of chemical additives. The utilization of agricultural pesticides has facilitated the enhancement of agricultural productivity for farmers. Nevertheless, this achievement has frequently been followed with the deterioration and devastation of the natural ecosystem. Numerous regions have encountered pollution of surface and underground water and soil resources as a result of the application of agricultural pesticides, leading to detrimental impacts on human health [1, 2, 3]. Pesticides and their residues in the food and feed sources of wildlife, domestic animals, and humans have been linked to serious health problems in people, such as cancer, chronic kidney disease, suppression of the immune system, sterility, endocrine disorders, and neurological and behavioral disorders [4, 5, 6].

Crop yields are measured by the amount of product produced from a sown area. Yield growth depends on the skeleton of the land, the proper selection and placement of available varieties and plant species resistant to natural influences and diseases, the creation and cultivation of new hybrid plant cell cultures, and the development and introduction of new progressive technological methods. There are many objective and subjective measures to achieve this growth, one of which is the control of weeds and diseases spread by weeds. According to experts, weeds and

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weed-borne parasitic disease pathogens are currently causing serious damage to cultivated plants [7, 8]. Therefore, one of the most urgent problems in crop production today is, first of all, to cleanse crop areas from diseases spread by weeds and weed vegetation. The main task of the complex of technical measures realized in the sown are a with the help of modern machinery and technical means is the timely cultivation of the sown area at the level necessary to obtain high yields. The complex aims to provide agricultural machinery and technical and technological measures in an intensive manner, to use the machinery efficiently, to implement the technological processes of crop cultivation in a timely and qualitative manner, and to further increase yields.

Crops such as cotton, grains, vegetables, and melons suffer from a variety of diseases in open fields and closed soils(greenhouses). In recent years, nematode diseases have caused serious damage to crop yields. Especially serious damage has been caused by vegetables, melons, and gourds grown indoors (greenhouses) [9, 10]. Tomatoes and cucumbers are the most consumed food stuffs, occupying the second place in production in the Republic after potatoes. The consumption of tomatoes and cucumbers is increasing because they contain vitamins and trace elements necessary for human consumption and are well preserved. Cultivation of these products is hampered by nematodes that develop on the roots of the plants. Namely, the northern nematode Meloidogyne hapla [11] belonging to the Meloidogyne Goel group, the southern nematode Meloidogyne incagnita, the Javanese nematode Meloidogyne javanica Treual, and the nut nematode Meloidogyne arenaria Neal.

Current nematode disease prevention methods include prophylaxis and mass extermination.

Traditional nematode disease prevention methods include the following: weed control, planting of uninfested seedlings, tools, special treatments, and sanitation; introduction of new nematode-resistant varieties, seed treatments, seed separators; use of chemicals for weed and disease control; electrically driven pre-sowing seed sorting.

Large-scale nematode disease control includes: crop rotation and tillage; physical control: paper or poly film covering (plastic mulch), use of electricity (UV, ultrasonic), laser light, and warm water; chemical control: use of dazomet, DD, bromomethyl, DDB, triazone, ammonium nitrate, superphosphate, oxymethyl, hetaphos, nemacur, bidat; biological control using Arthobotys, Trichoderma, Aspergukks, various outdoor and indoor small and wild fungi, Royal-350, formalin solutions, films, breeding plants (peas, Russian horseradish, beans, etc.) and wild parasitic plants; and methods using high voltage alternating current.

The use of manual labor to remove weeds and diseased crops from fields using the above methods and means is very labor intensive and costly, requires changes in technical processes and treatment sequences, and increases production costs. Therefore, the electric pulse treatment method can be used in any weather conditions, this method is climate independent, and most importantly, the electric pulse treatment method is very simple and environmentally friendly [12]. Pulsed Electric Field (PEF) procedure is one way to process food without using heat. It uses short pulses of electric current to stop microbial growth with the least amount of damage to the food's quality. This method not only keeps the product's nutritional value, but also keeps its physical and organoleptic qualities. As shown in Figure 1, the PEF method can be used to kill enzymes and microorganisms and to process meat, fish, egg products, dairy products, fruit, and vegetables [13].

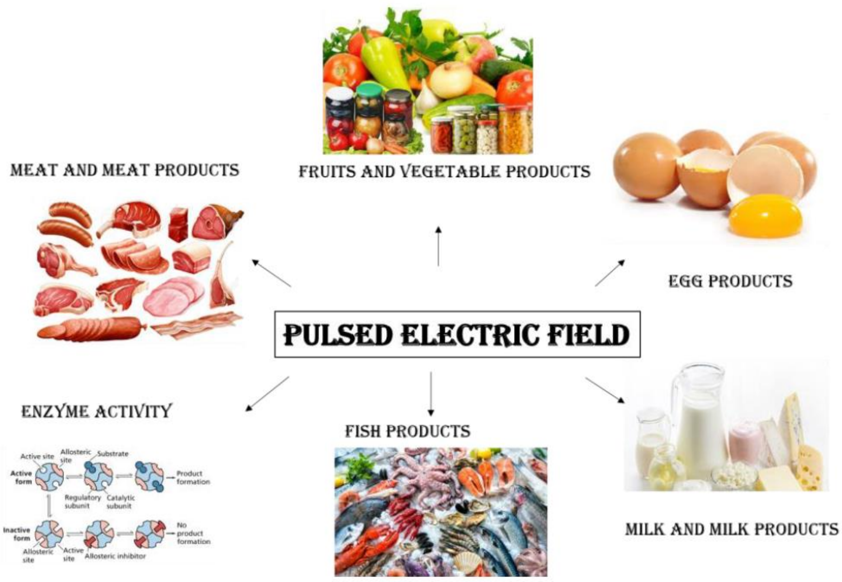

Fig. 1. Application of pulsed electric field on different products [13]

The results of scientific and technical data on the use of pulsed discharges on diseased cultivated plants indicate that the use of high voltage current discharges on cucumber and tomato rhizome parasitic nematodes has not been adequately studied.

2. Methods

The adverse effects of nematodes described above, in addition to the damage caused by plant infestations, also lead to yield reduction. The damage caused by nematodes and agriculture is very high, for example 80% in potatoes and 60% in greenhouse tomatoes and cucumbers. Nematode infestations account for 30% of costs in agriculture [14, 15, 16, 17, 18].

On the basis of years of research at the Institute of Irrigation and Agricultural Mechanization Engineers of the National Research University of Tashkent, a new technology for nematode control and an electric pulse device for its implementation have been developed [14, 15]. The proposed technology is characterized by its cost-effectiveness, environmental friendliness, and effective use of existing plant treatment technology. The application of this technology does not affect crop values and, most importantly, does not produce detrimental effects. It should be applied after summer harvest or during fall tillage.

Figure 2 is a schematic representation of the effects of electric pulse discharges on nematode-infected plants. Working procedure according to the scheme of Fig. 2: the positive electrode 5 is brought to the bottom of the stem, the negative electrode 6 is connected to the ground 10. After connecting the device 2 to the power source 1 between the stem 8 of the plant 7 and the roots 9 begins to flow electric current 11. High-voltage discharges of electric current pass through the nematodes infected plant roots spreading disease microorganisms 11.

Nematodes develop rapidly and have the ability to destroy root cell structure, forming voids and irregular ribbed thickenings. In stages III-IV, the bodies of mature female nematodes in the plant root system become round and bulbous. Mature female nematodesproduce100 to1,500larvae. The number of larvae produced by mature female nematodes can reach 3500. In vegetable crops of Central Asia and the Caucasus, female nematodes lay larval eggs 3-7 times per year [14-22].

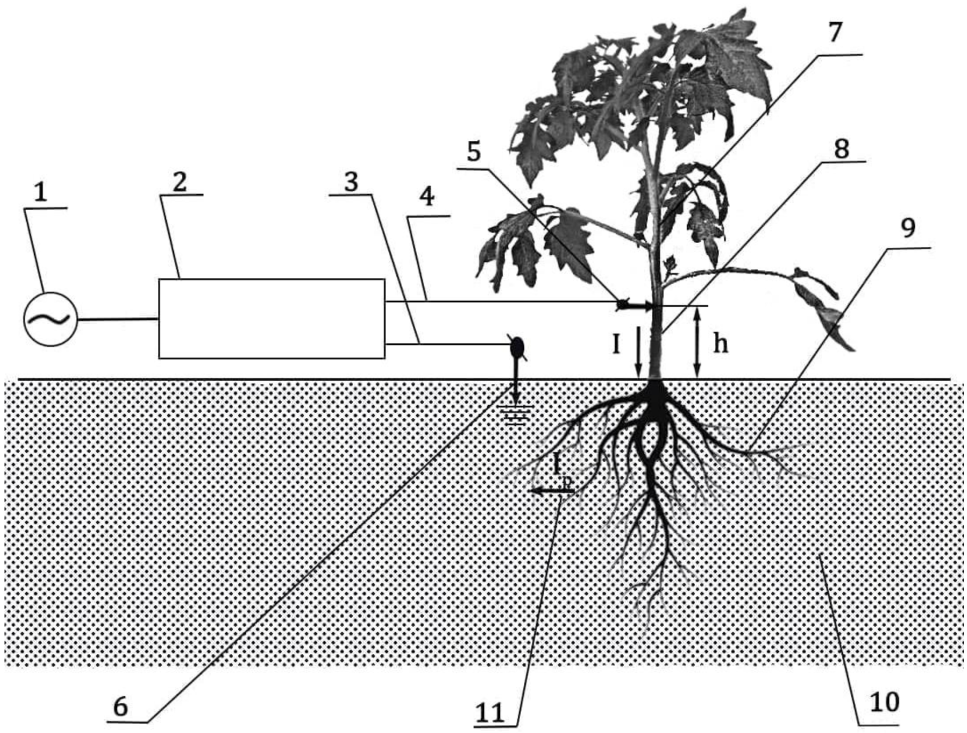

Fig. 2. Scheme of treatment with electric pulse discharge infected plants: 1 - current source; 2 - high voltage device; 3, 4 - high voltage wires; 5, 6 - electrodes; 7 - plant stem; 8, 9 - roots and neck of infested plant; 10 - soil (clay); 11 - nematode larvae

Experimental studies on the use of electric pulse discharge to control nematode virus vectors were conducted in the experimental plots of the cooperative farm "Muhammad Milonshok" in Oltinsoy district, Surkhandarya province. Field experiments on electric pulse treatment of virus vectors were conducted with the participation of entomologists from the cooperative farm.

3. Results and Discussion

Power is supplied from the 110 V mains supply and is converted to a step-up transformer using a laboratory autotransformer. The power transformer of the amplifier is mounted on the phase U1 = 0÷110 V and U2 = 0÷10000 V windings of a voltage transformer type S = 1.6 kVA type NOM-10. The secondary high voltage winding of the power transformer is connected to a KC-201 type E valve diode, which can supply positive or negative polarity discharge to the installation object. A battery of capacitors of varying capacitance is connected after the valve diode.

Table 1. Results from the treatment of pathogenic tomato and cucumber plants with pulse current discharges

№.	Experiment	Voltage, V.	Treatment time, sec.	Pulse energy, J.	Degree of neutralization, %	Damage level K_r
Tomatoes						
1	1	1000	0,2	0,0010	35	3,8
2	2	2000	0,2	0,0020	49	1,9
3	3	3000	0,2	0,0045	60	1,0
Cucumbers						
4	1	1000	0,2	0,0010	35	3,5
5	2	2000	0,2	0,0020	40	1,7
6	3	3000	0,2	0,0045	59	1,0

These capacitors make it possible to obtain different wavelengths, discharge energies, discharge currents, and pulse currents when generating pulsed discharges. Capacitor batteries have a spherical discharge gaps through which the pulse charge flows. By controlling the flow of the pulsed charge from an intermediate distance, its magnitude can be varied. This allows the form at ion of a discharge shock wave. Bronze material is used for the electrodes of the discharge gaps to prevent surface drying and smoke generation during lightning transitions. The positive and negative electrodes E1 and E2 are made of 3.5 mm diameter nickel-plated steel rods and 25cm long fiber wire cables. In the proposed device, the discharge current, voltage pulse, discharge energy, discharge pulse intensity, pulse shape, and treatment time can be varied when treating damaged tomato and cucumber rhizomes with electric pulses using an environmentally friendly and clean electrical method.

The current pulses affect the plant cell membranes and the surface of the nematode virus, thus disrupting and destroying the root nodule system and the nematode virus membrane. This method is applied after the infected plants have been harvested. Table 1 and Figures 2, 3, 4 and 5 summarize the results of experimental studies on pulsed current discharge treatment of diseased tomato and cucumber plants.

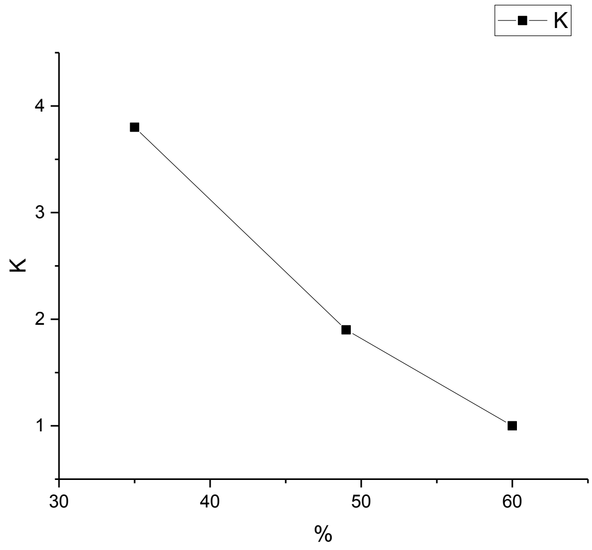

Fig. 3. Correlation graph of the level of neutralization with the level of injury

The solution to these problems is to study the following factors that contribute to the practical application and widespread application of treatments with strong negative effect son harmful parasitic diseases of plants, larvae, and galactic organisms: energy parameters(voltage, current intensity, treatment time) of pulses relative to the coefficient of resources (Kr), pulse discharge frequency, capacity, energy content); to determine and justify the parameters of treatment with electric pulse discharge; to study the anatomo-biophysical and morphological parameters of treatment with electric pulse discharge To study the anatomo-biophysical and morphological parameters of treatment with electric pulsed discharges. To study the anatomo-biophysical and morphological parameters; To study the anatomo-biophysical and morphological parameters of electric pulse discharge. Correlation between the level of damage and the level of neutralization is shown in this graph, i.e. in Figure 3, based on the table

A 30x30x50 plot in a greenhouse planted with tomatoes and cucumbers with a large nematode infestation was dug up and the plant roots and everything else placed on polyethylene film. Rhizomes were removed from soil and dirt so as not to damage them. This method was prepared by digging 15 samples of each plant [14, 15, 20, 21, 22].

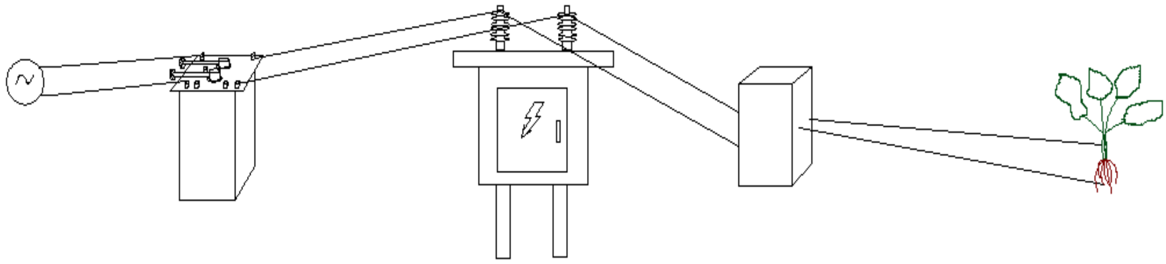

Fig. 4. Electrical pulse treatment process of tomato and cucumber roots washed out of the soil

Three different treatment methods were used in the electric pulse treatment of the plants.

-Treatment of diseased plants by removing soil and subsoil;

-Treatment of diseased plants by digging the soil and rhizomes out of the ground and placing them on polyethylene sheets;

-Treatment of diseased plants by removing the soil and subsoil;

-Culturing the rhizomes of diseased plants in the soil.

When selecting samples to be treated, it is necessary to consider the ingrowth stage, developmental stage, size, and the extent of nematode helminth infestation:

1. Dig up diseased plants in the following order take five samples labeled with special numbers from the greenhouse area from diseased tomato and cucumber plants with the same stem, height, and degree of infestation. Each plant is covered with polyethylene film (carpet), 30x30 cm^2 around the plant is cut with a plow and a positive electrode is fixed at a distance of 25 cm from the roots. The negative electrode is buried under the soil mass on a polyethylene mat and treated with electrical impulses using a laboratory simulator at a constant voltage level and for a constant treatment time. During the treatment, the diseased plant sand soil are treated by passing an electric current through the root hairs of the plant and the area in contact with the soil. Next, to evaluate the electrical effects in the diseased plants (Figures 4 and 5), the circuit of the electrical measuring device is assembled and measurements are made. To measure the electrical resistance of the treated rhizomes, a stainless steel metal needle 10 mm long is made, a hole is drilled in the organic glass, and the needle is placed 10 mm apart. A flexible shielded copper wire is welded to the back of the7 mm long needle protruding from the dielectric. After treatment, this measuring electrode is inserted into the rhizome of the plant, and the are a where the electrode is attached is wrapped in polyethylene film to protect the leads and moisture. The treated soil and rhizomes are then transferred and numbered in special, pre-prepared compartments. In an other plot of the greenhouse with clean soil infested with pests, a 30x30x50 pit is dug in a special are a and covered with a 3 mm polyethylene bag around it (to prevent pests from the outer soil and nematodes from the diseased soil from damaging the soil in the test plot). Samples are simultaneously treated with different voltages, discharges, and currents, numbered and measured in the above order; the fifth sample is control buried without treatment, a measuring electrode is placed in the fifth well, resistance values are measured, and recorded in a special notebook.

2. Diseased tomato and cucumber seedlings are dug up with out removing them from the soil, treated on a polyethylene bedding in the above order, and the rhizomes are transplanted in toa special plot with pro-numbered electrodes.

3. Select five plants from diseased tomatoes and cucumbers that are similar in size and growth stage to the experimental plants for soil treatment collected earlier. Insert the negative rod electrode of the Electro-Pulse Arrester to a depth of 25 cm, 50 cm a way from the rhizome of the plant. The positive electrode of the electro pulse arrester is attached to the plant stem with a special clip at a height of 25 cm from the rhizome-plant stem boundary (ground) an data position that does not cause mechanical damage to the plant.

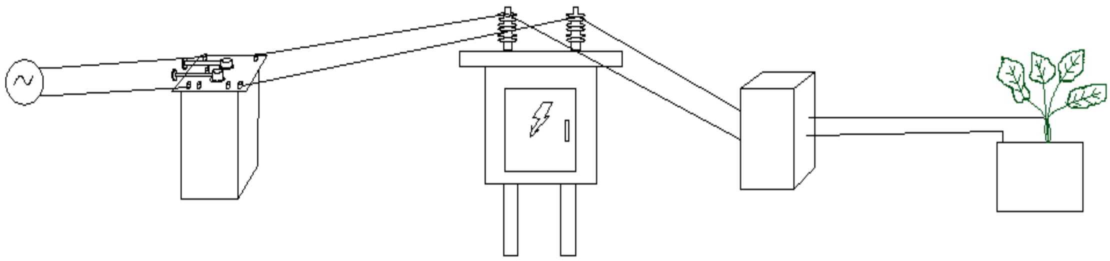

Fig. 5. Process of electric pulse treatment of tomato and cucumber roots not removed from the soil

4. Conclusion

Experimental studies on the application of the proposed method and equipment showed a 65-68% reduction in virus and nematode larval countsinl and treated with electric pulse discharge compared to untreated and field plots. Repeat trials showed a 15% reduction in nematode larvae before sowing in the second growing season.

Experimental studies on the treatment of pathogenic tomato and cucumber plants with electric pulse discharge showed its effectiveness sin the following parameters of electric pulse treatment: discharge voltage $U_{discharge}$ =3 kV, excitation time $\tau_{discharge}$ =0,2 s, discharge energy $W_{discharge}$ =0,0045 J.

Experimental study of biological effects of electric pulse treatment on nematodes high pulse discharge on the third day of treatment leads to destruction of nematode eggs.

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