



# Methodology and Modeling of the Application of Electrophysical Methods for Locust Pest Control

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**Abstract.** At present, despite the serious historical experience of locust control, these insects continue to cause serious damage to plantings and crops, both in our country and around the world. In world practice, monitoring of the emergence and movement of locust swarms across the territories and their destruction has been strengthened. But approaches to the extermination of insects remain the same as in the 20th century - the use of mechanical and chemical methods in the destruction of larvae, the use of pesticides and biological agents in the control of adults. All these options are characterized by the decrease in efficiency, are not environmentally safe, and insect resistance to constantly used pesticides and biological products is observed. The revealed fact of the presence of the large number of protein components in the body of the locust allows to speak about the need to use insects, after processing them, for livestock, poultry and fish feed, and studies reveal very good results in their fattening. Therefore, from the point of view of high technological efficiency, environmental and food safety, the most interesting option is the destruction of locusts using high-voltage electrical impulses. The use of electrical impulse technologies can be implemented both to combat larvae and to destroy adult individuals that can move along the surface of the soil cover. The general vision of such technical solutions has already been described in the patent literature and even implemented in practice, but often these are purely design options that are not consistent with serious laboratory and field studies. Therefore, the integrated approach, containing an experimental study of the operation of installations and the reaction of locust insects to the proposed regimes, will allow developing technical installations, identifying the most efficient and energy-saving ones of them, characterized by high technological performance and minimal environmental damage.

**Keywords:** Locust insects · Larvae (pods) · Adults · High-voltage electrical impulses · Ultraviolet radiation · Block structure · Electrotechnological installations

## 1 Introduction

Locusts are one of the oldest types of migratory insect pests, the vital activity of which causes significant damage in the crop production, which affects the entire agriculture as a whole, and this applies not to a single region, but to the entire global agricultural industry. Thus, the extent of damage to soil areas, estimated by the Food and Agriculture Organization of the United Nations (FAO), reaches 20% of the entire land area on the planet, covering the territory of more than 60 countries [1].

In the basis of the applied methods of locust control is the main rule - to assess correctly the scale of the disaster and be ready for its destruction, which is the first task of the FAO Global Desert Locust Information Service (DLIS).

The main methods of destruction of locust pests are determined by the experience of historical struggle with them - this is, first of all, mechanical autumn plowing of those areas of the soil cover, in the thickness of which there are locust larvae (pods); collection and burning of adults; the use of pesticides for insect control, and above all, the treatment of the territory by spraying insecticides from aircraft; the use of biological products, for example, entomopathogenic fungi, etc. [2, 3, 18]. Such approaches have both the estimated effectiveness of their application and the identified negative consequences of their use. Mechanical methods are often characterized by low efficiency, due to the fact that the egg-pods (larvae) of the locust are located on areas that are inconvenient for cultivation, slopes, along the edges of plantings, canal banks, etc. [2, 19]. The use of pesticides is officially recognized as having a negative impact on the health and life of animals and people [4, 22]. Biological methods of control are environmentally safe, but lead to possible resistance of locust insects to various fungi and their spores [5, 20, 21].

Therefore, today very close attention is paid to the search for new effective, low-energy, environmentally friendly methods and ways to control locust pests, using, first of all, for this effect of the electromagnetic nature, which is considered to be the use of microwave and EHF energy, high-frequency currents, continuous flow of conduction currents through the biological object or by exposure to high voltage impulses [6, 24].

The use of microwave energy for the continuous processing of the soil mass, in which the larvae (pods) of the locust are located, is fraught with the negative impact on the soil biota, since it contains a huge number of beneficial microorganisms and bacteria that, when exposed to microwave radiation, will die, having lost their soil-organizing properties and its natural fertility [7, 23].

The application of currents of direct or alternating voltage of the EHF range flowing through soil volumes for the long time requires serious expenditures of electrical energy and is accompanied by its unproductive conversion into thermal energy [8].

Therefore, both from the point of view of technological efficiency and environmental safety, the use of high voltage impulses for these purposes may be of research and practical interest [9, 25]. The possibility of using electrical impulse effects of lethal doses to control pests, harmful insects and diseases spread in the soil under crops and planting crops was noticed back in the 18th century [10].

Today, these studies are more relevant than ever, and they are continued in laboratories and research centers, providing new information about the mechanisms of irreversible damage to biological tissues of insects, developing new technical means, improving

applied electrical technologies, reducing total energy costs and not causing damage to the environment.

## 2 Objectives of Studies

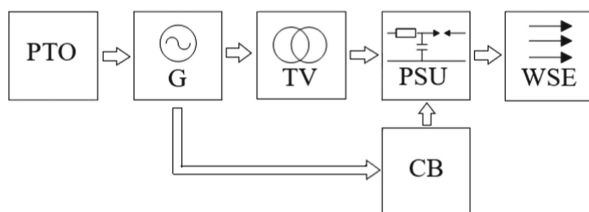
The purpose of the article is to consider the general approaches and principles of electrical impulse processing of soil massifs with ovipositioning (pods) of locusts for its destruction, as well as attracting and irreversible electrical impulse damage to adults, with the aim of further processing it for feed for livestock, poultry and fish.

## 3 Data and Methods

High-voltage electrical impulse technologies can be effectively used both in the destruction of locust larvae (pods) in the soil, and in the fight against adult individuals that can move independently on the soil surface. Two approaches were considered to evaluate the knowledge of the issues and give a more substantial justification for the proposed solutions.

The oviposition of locust females, laid at the end of summer in the upper soil layer at the depth of 5–6 cm, winters in the so-called egg-pods, which are formed by hardened insect secretions mixed with earth particles cemented outside. Depending on the type of locust pests, the number of eggs in the capsule varies from 50 to 150 pieces. The main measures to reduce the number of viable egg-pods are agrotechnical methods - plowing, harrowing, applying soil pesticides, etc., with which you can achieve a destruction efficiency of 95–100%. But these methods are effective if all territories with oviposition (pods) laid on them are subject to processing, which in practice is not always possible to implement [11].

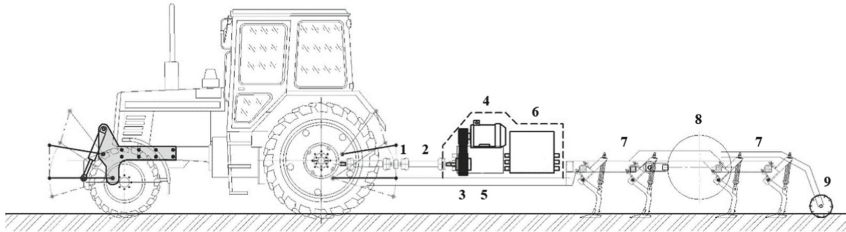
It is possible to implement technically the option of combating locust larvae in the soil using a mobile unit, the block structure of which is presented at the Fig. 1.



**Fig. 1.** Block structure of the unit for electrical impulse processing of the soil mass with locust egg-pods in it: PTO - tractor power take-off shaft, mechanical energy source for driving the electric power generator G; TV - step-up voltage transformer; PSU - high voltage electrical impulse generation unit; CB - control unit, for example, to set the repetition rate of the acting discharges; WSE - system of working electrodes buried in the soil

From the point of view of the technical equipment of such a hinged electrotechnological installation (Fig. 2), it should be noted that separate study is required on the shape

and configuration of the working electrodes, their connection into groups or sections, as well as the justification of the processing modes of the electrotechnological hinged installation - the parameters of high-voltage impulses (amplitude value, duration and energy of a single pulse, the repetition rate of the acting pulses) supplied to the soil areas.



**Fig. 2.** Sketch of the unit for electrical impulse processing of the soil mass with locust capsules in it, which is the electrotechnological installation mounted on the wheeled tractor: 1 - tractor power take-off shaft; 2 - cardan shaft; 3 - belt drive; 4 - electric power generator; 5 - step-up transformer; 6 - block for the formation of high-voltage electrical impulses; 7 - system of potential working electrodes buried in the soil, in the form of cultivator paws; 8 - transport wheel; 9 - support wheel-copier of the soil surface. The control unit and the electrical safety monitoring system are located in the tractor cab for constant monitoring of the processing progress by the operator-driver

The electrode system should not create significant additional traction forces for the mover and, at the same time, effectively supply electrical impulses to the cultivated soil mass, in which the locust eggs are located. On the one hand, these requirements can be met using simple, already available technical solutions for electrodes in the form of operating device of agricultural machines - cultivator paws, slotted knives or disk bodies, and on the other hand, taking into account the fact that the capsules are located at a shallow depth from 5 to 6 cm and represent, in terms of laying, a kind of extended “ribbon” structure, adjustments may be required in the form of designing a special profile and configuration of the electrodes used for this purpose.

The system of operating buried electrodes must distribute the impulse effects in the soil volume with larvae in such a way that it is completely covered by the lines of the flowing conduction current. Therefore, such an implementation is technically possible both in the variant of symmetrical placement of potential electrodes and one or more common electrodes, and in the variant of using sectionally or pairwise installed potential and common electrodes.

Taking a comprehensive approach to the consideration of the problem of locust oviposition destruction in the soil, it is impossible not to dwell on the issue of the effect of high-voltage impulses on soil biota. The processing of egg-pods not only irreversibly damages and destroys the latter, but also, in accordance with the results of numerous experiments conducted to study the effect of electrical impulse and electrohydraulic treatment on the soil, most likely will lead to the post-effect growth of nitrogen-fixing bacteria in the soil and the appearance of organic components available for better assimilation by plants, which will ultimately affect its fertility and improved organic nutrition

of the vegetation cover. The conducted studies allowed to obtain results that indicate that, depending on the parameters of the discharge and the type of microorganisms, high voltage impulses in the soil can both inhibit and stimulate the development of these microorganisms. Electrical impulse tillage contributes to the increase in mobile compounds of potassium and phosphorus by 1–2 mg/kg of soil, thereby allowing to increase the grain yield by 0.1–0.12 q/ha. In parallel, there is an increase in humus in the soil up to 7–9% of its initial content of 2.65%. The increase in vital activity is observed for the most unpretentious microorganisms - oligonitrophilic bacteria, which contribute to the growth in the assimilable forms of nitrogen in the soil, and fungi. It should be noted that tillage to enhance the vital activity of microorganisms should not be carried out under strict conditions, that is, with a high processing energy density [12].

## 4 Results and Discussion

The main task that must be solved when destroying adult locusts is the task of how to attract adult insects to the electric treatment area.

Research scientists from the Chinese Academy of Sciences have found that the collection of adult locusts into electric treatment area can be carried out due to the release of volatile substances by insects, such as 4-vinylanisole (4VA) [13].

Almost all insects see ultraviolet rays, perceiving them as light of the certain wavelength [14]. When various insects were placed in chambers illuminated from two sides with two beams of monochromatic light of different wavelengths, it almost always turned out that the attractiveness of the ultraviolet rays was 4–6 times higher than the other rays of the spectrum. According to the results of numerous experimental studies by Nihon Gairoto Seizou KK, it was concluded that insects are attracted to ultraviolet radiation with a wavelength of 340 to 350 nm [15]. Researchers from the Astrakhan State Technical University drew attention to the fact that locust insects have additional photoreceptors that effectively detect exactly ultraviolet radiation [16].

It is the results of studying the reaction of insects to ultraviolet radiation that can be used as the basis for attracting adult locusts to the electric treatment area.

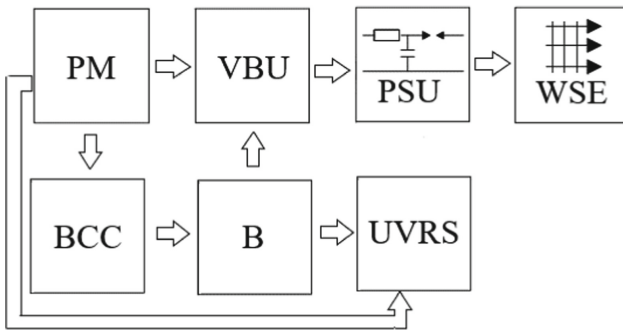
It is technically possible to treat adult locusts using two solutions: 1) by placing a hinged structure or platform with the electrotechnological installation placed on it, for attracting and subsequent electrical treatment of insects, for example, in front of or behind the cabin of the wheeled tractor, providing electrical impulses to external, conducting electric current, fencing of the working space, from the installation located on the tractor, which generates electrical voltage and generates high-voltage impulses; 2) using the electrotechnological installation permanently placed on the soil surface, which is a three-dimensional structure closed around the perimeter by the metal conductive mesh, organizing power supply from the autonomous electrical energy source to that part of the installation in which insects are attracted by ultraviolet radiation, as well as organizing the formation and supply of electrical high-voltage impulses to the outer perimeter of the enclosing conductive surface. In both cases, it is necessary to design structures for the convenient collection of immobilized locust insects.

As a prototype of the technical solution option in the form of the stationary electrotechnological installation, it is possible to take devices already produced by the industry for the destruction of flying insects, insect traps, etc. These devices, using light radiation of the certain wavelength, attract insects, which, flying very close to the light source, come into contact with the metal conductive outer fence that is under a certain electrical potential and after contact with the fence, the insects are irreversibly damaged and fall into the collection tray placed directly below the device.

The possibility of adjusting the shape of the very design of the electrotechnological installation should be considered, since there is primary research information that not flying insects, but those of them who have not yet taken the “wing”, but move, bouncing above the soil surface, are the most attractive material for cooking feed for farm animals, poultry and fish due to the higher content of protein compounds in them. Therefore, the most effective is the collection of locusts during this period of development, and this is 2–3 weeks from the its appearance out of the egg-pods, when young insects remain practically settled in one place [17].

The nutritional value of such feed for livestock, poultry and fish as locust meal has no equal, as it surpasses all existing animal proteins added to feed. Pork and lamb contain 17% protein; in fish it is 21%; and in individuals of locust it is 75%. If an absolute estimate is made, then the “efficiency of locust” in terms of protein production exceeds cattle by more than 25 times.

The block diagram of the proposed design of a stationary electrotechnological installation is presented at the Fig. 3.



**Fig. 3.** Block structure of the stationary electrotechnological installation for electrical impulse irreversible damage to adult locusts: PM - photovoltaic solar module; BCC - battery charge controller; B - storage battery; VBU - voltage boosting unit, up to the required technological level; PSU - high voltage electrical impulse generation unit; WSE - working electrodes, in the form of the conductive grid that encloses the internal space; OVRs - ultraviolet radiation source placed in the interior of the installation

The power supply system of the stationary installation proposed for design will have high reliability and will be able to operate uninterruptedly if solar photovoltaic modules mounted on the roof and coupled with batteries act as a power source and its backup, which will allow them to be charged from these modules during the daytime, and work offline at night.

## 5 Conclusion

After analyzing the specialized information available in the open press on the physiology of insects, their response to light and photo effects, the features of the influence of electrical effects on their viability, after analyzing the designed methods and technical solutions for combating harmful insects, it can be concluded:

1. The impact of high-voltage electrical impulses should be considered as the most effective type of impact of the electrical nature, being technologically effective both for combating locust larvae in the soil and for immobilizing adults;
2. To combat locust larvae, a mobile unit should be used, which is a mounted electrotechnological installation on a wheeled tractor, which, through the application of the system of working electrodes, allows high-voltage impulses to be applied directly to the oviposition, irreversibly damaging locust larvae;
3. To combat adult locusts, it is recommended to use a stationary design of the electrotechnological installation, which is a block of light attracting insects based on ultraviolet radiation, and a design with the grid-electrodes to immobilize adults;
4. Collected after electrical impulse processing, locust, prepared in an appropriate way, is the basis for the manufacture of high-protein feed, which can be used for fattening animals, poultry and fish.

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