EFFECT OF ULTRA-BRIGHT LED LIGHT FOR LOCUST PLAGUE CONTROL

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Abstract. Locusts and grasshoppers are among the most dangerous agricultural pests. Their control is critical to food security worldwide and often requires governmental or international involvement. Control of pests such as insects has evolved from hand slaps to fly swatters, to chemical insecticides, electric bug traps, glue covered strips, and other devices. Often an attractant, such as ultraviolet light, scent or edible bait, is used to lure insects or rodents into the trap. In one common trap, ultraviolet light attracts insects onto an electrified grid which then electrocutes the insects. This device, however, sparks loudly, spatters debris, and is dangerous to humans. Mechanical traps also have drawbacks, for example, the need to lure the pest into a small space. Chemical pesticides can poison non-target species and pollute the environment. The biological pesticide has a high cost, and has several days delay between spraying and killing locusts. Energy devices such as lasers have been proposed for use against insect pests, against flying swarms of locusts. The latter method recognizes that destroying the insects completely would require too much energy, and therefore targets a specific organ structure, such as wings or sensory organs, to render the insects unable to fly. Even so, the energies described are too large for practical use using the method suggested. Also, the cost of the lasers is quite high. To explore new physical means in controlling locusts, the LED-device was used to evaluate the effect of LED light on locusts. The results indicated that the locusts were trapped (near 100 %), when the color of light emitted from LED is blue, green, yellow, red mixed in a special order. The application of the obtained algorithm and the duration of activation of light-emitting diodes allowed to increase the number of caught individuals up to 5678 pieces.

Keywords: LED, laser, locust, pests.

Introduction

Locusts (Orthoptera order, Caelifera suborder, Acridoidea superfamily) are the most harmful pests in agriculture both in the Old and in the New World. The species that provide the migratory swarm form with a high population density are of particular danger. These species have received the collective name of the locust or swarm locust. There are more than ten locust species in the world. The most part of them provide outbreaks of mass reproduction, which are registered periodically and cause enormous economic damage [1].

The most effective way to control the locust is its catching at the age capable of laying eggs. As a rule, at this period the locust gains the ability to fly (to take wing) and is the most dangerous pest, common in large areas. There are no other effective methods of its control that do not cause any undesirable environmental impacts. The high cost of pesticides and aero-treatment as well as low efficiency of their use resulted in an increase of locust population in the southern regions of Russia and Kazakhstan, which caused a threat to the agriculture in these regions.

In the locusts' life cycle a number of authors distinguish three dominant periods. The first period is the time of mass egg-laying in places called nestlings. The second one is a period during which locust larvae live in close crowds called swarms up to the time of taking wing. The third period is a period of schooling, when the locust individuals' wings become strong and they migrate over long distances [2-3].

There are developed, mainly chemical, methods of locust destruction during the first two periods. But the use of chemical or biological pesticides is of high cost, and, besides, several days delay is needed between spraying and locust destruction.

As for the schooling period, the implemented methods of locust destruction do not exist. Due to the development of sources of electromagnetic radiation, proposals appeared to destroy insects, including locusts, with the help of SHF- radiation, microwave radiation and laser radiation.

A number of authors propose to destroy pests of animal and vegetable origin by affecting them with SHF- radiation [4-6]. This method uses electromagnetic radiation with a wavelength bigger than the locust size, and therefore, the destructive effect is achieved by heating the whole body of the individual to a temperature that causes the death of the insect. Such methods are unsuitable for the destruction of migratory locust swarms.

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Other authors propose to destroy insects, including locusts, with laser radiation of different spectral range in a certain allocated volume, where the locusts are attracted to by baits of different types of action. This method uses a mobile laser radiation source (a Nd-YaG laser, a chemical laser, a CO_2 laser) with a power up to 10 kW, operating in continuous or repetitively pulsed modes. In this case, the laser is equipped with a special computer scanner, which by means of pattern recognition distinguishes an individual in a swarm and tracks its movement, and the laser radiation is focused on a selected part of the body of an insect as a spot of 2 mm in diameter. After that the radiation targets at the next individual. Thus, the destruction of the flying locust swarm in parts is possible. A swarm that fails to follow collective behavior is deprived of the possibility of further movement and can be destroyed by other means [7-9].

The latter method recognizes that the complete destruction of insects will require too much power, and therefore it is aimed at a specific structure of body organs, such as wings or sensory organs, to make the insects unable to fly.

Also, the cost of the lasers is quite high. The aim of the authors of the article was to study new physical means in the fight against locusts, the use of a LED device to evaluate the impact of LED light on locusts, when the color of the light emitted by the LED is mixed in a special order: blue, green, yellow, red.

Materials and methods

Experimental studies on locust attraction and trapping with a LED device were carried out in 2016-2018, usually in May, at the time of the locust invasion on the eastern part of the Stavropol Territory of the Russian Federation.

The main devices used for locusts attraction were light-emitting diodes of blue, red, green, yellow color. Super-bright light-emitting diodes based on InGaN, InGaAlP, GaAlAs, GaInN, etc. crystals were used as the emitting LEDs. Light-emitting diodes were installed on special sectional panels in various combinations. For example, Figure 1 shows blue and red LEDs installed in a device for catching and destroying locusts.

Fig. 1. **Sectional panel with light emitting diodes of blue and red colors**

The main parameters affecting the efficiency of catching and destroying locust are the distance from the device to the locust swarm, the wavelength of the light-emitting diode. Experimental studies used blue LEDs with a wavelength range of 440...470 nm, green LEDs with a wavelength of 510...530 nm, yellow LEDs with a wavelength of 560...590 nm, red LEDs with a wavelength of 620...640. These LEDs are widely used in the world and can be easily purchased. Since there are no clear boundaries defining the wavelength of color, the range is selected from the LED manufacturers' reference information.

The efficient distance, at which the brightness of the LEDs attracted locusts, was 10 meters or less during the daytime and 50 meters or less at nighttime.

In order to count the trapped locust individuals, a specially designed counter device was used. Destruction of locusts caught in the trap was carried out with using of a metal grid, which was supplied with the voltage of 5000 V. Power supply to the device for locust catching and destruction was carried out from accumulator batteries, or from a mobile gasoline generator with a power of 1 kW.

For the statistical analysis the STATISTICA 12 program was used [10-11].

During the experimental studies, the effectiveness of the traps was determined by the number of the caught individuals. On the locusts' way, in various places, traps were installed containing light-emitting diodes of only one color. After the locusts overfly, the caught locust individuals were counted and a comparison of the effectiveness of the traps was made. The caught locusts were later used as a feed additive for fish in ponds.

Results and discussion

As a result of the experiment it was established that the largest number of caught locust individuals was obtained in the traps, where blue light-emitting diodes were installed with a wavelength of 440...470 nm. (Table 1).

Table 1

Efficiency of traps of 4 colors

Trap number	Color of light emitting diode	Wave length, nm	Number of caught individuals
1	Yellow	560...570	647
2	Yellow	570...580	1307
3	Yellow	580...590	1928
4	Blue	440...450	3320
5	Blue	450...460	2428
6	Blue	460...470	2163
7	Red	620...630	72
8	Red	630...640	58
9	Red	630...640	64
10	Green	510...520	601
11	Green	520...530	536
12	Green	520...530	526

Also, satisfactory data on the number of the locust individuals caught was obtained in the traps containing green LEDs with a wavelength of 510...530 nm and yellow LEDs with a wavelength of 560...590 nm, however, the number of the insects caught in them is less than in the traps with blue LEDs. For the traps with blue LEDs a trend has been identified that with a decrease of the wavelength, an increase in the number of caught locust individuals occurs. Indeed, with a wavelength of 460...470 nm, the number of caught locust individuals is 2163 pieces and with a wavelength of 440...450 the number of caught locust individuals reaches 3320 pieces, and this is 53 % more. The traps with red light-emitting diodes with a wavelength of 620...640 nm showed the worst result in locust catching, therefore the use of such traps does not have a useful application.

Obviously, it is necessary to further investigate the light-emitting diodes of a wavelength less 440 nm. A wavelength less 440 nm belongs to the violet spectrum.

Also, the authors carried out experimental studies on simultaneous switch on of several light-emitting diodes of different colors, switching on sequences and various combinations. It was established that, if the number and time of lighting of different light-emitting diodes were changed, the number of the caught locust individuals would increase 1.72 times. The algorithm and duration of the LEDs are given in Table 2.

In the result of following the algorithm and duration of the LEDs lighting given in Table 2, the number of the caught locust individuals was 5678 pieces per trap. However, this requires additional electricity costs for correct operation of the timer and the device for switching on the light-emitting diodes.

Table 2

The algorithm and duration of LEDs lighting

Sequence of activation	Color of light emitting diode	Operating time of the light-emitting diode, sec
1	blue	1.0
2	green	0.5
3	red	0.5
4	yellow	1.0
5	blue, green	0.5
6	blue, red	0.5
7	blue, yellow	1.0
8	green, red	0.5
9	green, yellow	1.0
10	red, yellow	1.0
11	blue, green, red	1.0
12	blue, green, yellow	1.0
13	blue, red, yellow	1.0
14	green, red, yellow	1.0
15	blue, green, red, yellow	1.0
16	blue, etc.	1.0

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Conclusions

1. It is possible to use green, yellow and blue light-emitting diodes in traps for attracting locusts.
2. The most effective are traps with blue LEDs with a wavelength of 440...470 nm.
3. The maximum number of caught locust individuals of 3320 pieces is observed at a minimum wavelength of 440...450 nm.
4. Promising are the studies of traps with light diodes having a wavelength less than 440 nm, such a wavelength belongs to the violet color according to the spectrum of visible radiation.
5. The application of the obtained algorithm and the duration of activation of light-emitting diodes allowed to increase the number of the caught individuals up to 5678 pieces, however, it demanded an increase in the cost of the equipment and an increase in the cost of electricity for proper operation.

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