Comparative assessment of the efficiency of light traps of various design in corn agrocnosis

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Abstract. The North Caucasus region in its natural and climatic conditions is a zone favorable for the cultivation of corn in Russia. Significant damage to corn plantings and crop quality is caused by a variety of pests. In connection with the annual crop losses caused by harmful insects, the development of methods for their monitoring and capture are relevant. The efficiency test of two designs of light traps based on super bright LEDs (conical and aspiration) was performed. As a result of the experiment, which lasted for two weeks, more than 260 thousand specimens of insects belonging to 8 orders and 27 families were captured. The traps were most attractive for the representatives of the coleoptera, the proportion of which was 97.5%. Traps were also highly effective in relation to Lepidoptera (1%) and Hemoptera (1.4%). Representatives of other taxa were caught in much smaller quantities; their total share was less than 0.1% of the total. The use of test traps showed their high efficiency for the elimination of the main lepidopteran maize pests - Helicoverpa armigera Hbn. and Ostrinia nubilalis Hbn., which allows them to be used not only for monitoring but also for plant protection. The low attractiveness of traps for Hymenoptera was also revealed, which allows combining their use in the system with the use of entomophages. A comparative assessment of the effectiveness of attracting insects with various designs of light traps in the corn agrocnosis showed the absence of significant differences in species diversity and mathematically significant differences in the number of attracted insects: the conical trap was almost two times more effective.

1. Introduction

Corn is a culture of universal significance: food, feed and technical. In the world, sown area under corn is about 162 million ha, and grain production is more than 300 million [1]. In Russia, in 2018, the cultivated area under corn amounted to 2887 thousand ha [2]. Despite the high potential crop yield, direct harvest may be significantly lower than expected, due to high losses from pests. On corn, a high variety of pests is noted, of which the most harmful are the nutcracker beetles (Elateridae), the corn (stem) moth (Ostrinia nubilalis Hbn.), the cotton scoop (Helicoverpa armigera Hbn.), the corn beetle Diabrotica (Diabrotica virgifera virgifera Le Conte), Swedish fly (Osinosoma frit L.) and others that can provoke yield losses of up to 70% [3-5]. In connection with annual crop losses caused by harmful insects, the development of methods for monitoring and catching pests is relevant.

In the organization of plant protection from pests, an important role is given to phytosanitary monitoring, which makes it possible to determine the appropriateness of protective measures and...
establish their optimal timing. Recently, the use of super-bright LEDs for attracting (monitoring) and capturing (killing) insects has been of great interest. It is known about the independent development of various designs of light traps, including those based on super bright LEDs, in Russia and abroad. The devices are designed both for monitoring and reducing the number of insects [6-16].

To monitor and control the number of crop pests, the All-Russian Research Institute of Biological Plant Protection develops autonomous light traps of various designs with various combinations of LED spectra. As a result of many years of testing [17], the most effective combinations of the emission spectra of LEDs by the number of attracted insects were identified. Traps of aspiration and conical constructions have been developed and tested in gardens, in comparison with pheromone traps and Malez traps [18] and wild-growing forbs [19].

The purpose of these studies was to conduct comparative tests to assess the efficiency of insect capture by the number and species diversity of two trap designs based on super bright LEDs in corn agroecososis

2. Materials and methods

The research material was traps of insects of various designs created on the basis of the Federal State Budget Scientific Institution All-Russian Research Institute of Biological Plant Protection: conical [20] and aspiration [21].

A feature of the studied devices is autonomy, the use of superbright LEDs and various insect receiver designs. For faunal studies, a closed insect receiver is used with the ability to preserve attracted insects. For mass capture of pests, a separating insect receiver has been developed, which contributes to the release of smaller insects, including representatives of the Hymenoptera order, in comparison with the main capturing object. The principle of light traps operation is based on the use of positive phototaxis of insects to attract them in the dark.

A design feature of the conical trap is the arrangement of the LEDs in a circle, while the light beam from each LED partially blocks the emission of the neighboring ones, and therefore a uniform glow is provided, covering 360° in the horizontal plane. The trap contains a lid with a built-in solar battery, to which there are attached two vertically arranged mutually perpendicular plates of acrylic plexiglass, mounted on the cone of the light emitter. At the bottom of the device, there is a cylinder to which a bag for collecting insects is attached (insect receiver). On the underside of the cover there are light sensors with photosensitive elements. As the attracting elements, there was used LED strip with a wavelength of 395–400 nm above and a white glow below (color temperature 5000 K). Thanks to the photo relay, the LEDs turn on automatically at dusk, turn off at dawn. In high light conditions, the battery recharges from the solar panel.

The principle of operation of the aspiration trap is based on the presence of an aspirator in the body of the device providing forced suction of insects in the insect receiver. The peculiarity of this trap is the directional angle of light radiation, which is 170 degrees in the horizontal plane and high energy intensity, which requires the installation of a battery and a solar battery of greater power. Otherwise, it is similar to a conical trap.

Trap efficiency was tested under the same conditions, on the production fields of Kuban Canned LLC in the Dinsky district of the Krasnodar krai (45˚27’N, 38N93’E) on an area of 60 hectares in 1 to 2 decades of July. This area belongs to the steppe zone with average annual meaning of rainfall of 500-700 mm. The tested trap designs were installed at distances of 100 m from each other. Traps were controlled automatically using the built-in photo relay.

Samples were taken for two weeks, every 1 to 3 days, as the insect receiver was filled in the morning after the traps were turned off. Samples were placed in a refrigerator to fix collected objects, then the number of insects was counted.

Samples were formed in compliance with the rules of random selection, in accordance with generally accepted methods [22]. Under laboratory conditions, the captured insects were sorted and counted the number of individuals of each species belonging to different orders and families. Species
diversity was estimated using the Margalef index [22], and dominance was assessed using the Berger – Parker index [23].

The Berger-Parker index reflects the relative importance of the most abundant species, but since the ratio between the abundance of species obeys general laws, this index describes the general state of the biota quite accurately and takes values from 0 (no dominance) to 1 (absolute dominance).

Combinations of the number of identified species and the total number of individuals of all species underlie the indicator of species diversity. The larger the Margalef index, the greater the species diversity.

The reliability of the differences in the indices was determined by calculating the actual values of the Student’s criterion and comparing with the critical values for a specific sample size in accordance with the methodology [24] using the MS Excel program.

3. Results

Considering the absolute number of captured insects, a significant difference was found between conical and aspiration traps. The conical trap turned out to be almost two times more effective - during the experiment, the total number of insects trapped by it amounted to 171648 individuals, while the aspiration trap - only 97102 specimens of insects. These differences are easily explained by the different sector of space illumination, which is almost twice as narrow in the aspiration trap. Thus, the presence of a fan to suck in attracted objects does not have a visible effect in the total catch of insects.

As a result of the analysis of the collected material, representatives of 8 insect orders were identified. The maximum number of insects attracted belonged to the orders Coleoptera, Lepidoptera, Heteroptera, Hymenoptera, Neuroptera, Orthoptera, Diptera, Odonatoptera (table 1).

Table 1. Number of captured insects by traps in experiment

| Order         | Trap type | conical | aspiration |
|---------------|-----------|---------|------------|
| Coleoptera    |           | 167422  | 94626      |
| Lepidoptera   |           | 2115    | 693        |
| Heteroptera   |           | 2066    | 1712       |
| Hymenoptera   |           | 25      | 63         |
| Neuroptera    |           | 12      | 4          |
| Diptera       |           | 4       | 4          |
| Orthoptera    |           | 3       | 0          |
| Odonatoptera  |           | 1       | 0          |
| Total         |           | 171648  | 97102      |

Of these, coleopteran insects were most effectively attracted, the total number of which in the conical trap was 167422 specimens, and in the suction trap - 94626.

There were no significant differences in the number of insects captured by a conical trap from the Lepidoptera and Heteroptera orders, and amounted to 2115 pcs. and 2066 pcs., respectively. However, in the suction trap of butterflies it turned out to be 2.5 times less than insects from the order Heteroptera, lepidopterans there were 693 specimens, bugs - 1712.

The attraction of hymenopteran insects (Hymenoptera) turned out to be insignificant. Only 25 specimens were captured with a conical trap, 63 were aspirated. This result, especially in comparison with the preceding orders, indicates the possible use of light traps of this type for the mass capture of insect pests, with minimal impact on the useful entomofauna (the vast majority of captured hymenopterans are entomophages). A more effective involvement of hymenoptera representatives with an aspiration trap is explained by the forced absorption of attracted insects, which makes it possible to more effectively capture small objects.
In the collections of both traps, hard-winged insects belonging to 9 families are maximally represented. Most of them are aquatic and near-water beetles from the families Heteroceridae, Hydrophilidae, Scitidae and Dytiscidae, whose adults always fly well into the light. The predominance of representatives of Heteroceridae and other aquatic organisms (99.3% of the total number of beetles) can be explained by the presence in this area of a large number of natural and artificial reservoirs and watercourses. Entering the traps of soil flying predatory beetles - Staphilinidae and Carabidae, which are represented by entomophages, is, of course, a negative factor, but their mass death can be avoided by selecting the mesh diameter of the insects, through which they must pass freely, since they are small in size. Representatives of several species of nutcrackers are collected in small quantities, which indicates either their low density in the agrocenosis, or the mismatch between the summer of adults and the time of the experiment.

Lepidoptera insects in the collections were represented by four families: Pyralidae, Crambidae, Noctuidae, and Sphingidae, with scoops and fireworms accounting for almost 100% of the catch.

As for hymenoptera, both traps turned out to be the most attractive for representatives of Ichneumonidae; Braconidae and Proctotrupidae species were found in only four specimens for the entire duration of the experiment. This situation requires additional studies, since it is very necessary to find out whether the low attractiveness of traps is characteristic of these insects, or whether their number in the agrocenosis was simply vanishingly low (table 2).

**Table 2. Families of insects captured during experiment.**

| Order     | Family        | Trap type | conical | aspiration |
|-----------|---------------|-----------|---------|------------|
| Coleoptera| Heteroceridae |           | 164392  | 92466      |
|           | Elateridae    |           | 49      | 177        |
|           | Scitidae      |           | 184     | 0          |
|           | Dytiscidae    |           | 7       | 0          |
|           | Carabidae     |           | 529     | 527        |
|           | Hydrophilidae |           | 1979    | 1337       |
|           | Staphilinidae |           | 274     | 118        |
|           | Dermestidae   |           | 2       | 0          |
|           | Silphidae     |           | 6       | 1          |
|           | Pyralidae     |           | 1       | 4          |
|           | Noctuidae     |           | 1515    | 440        |
| Lepidoptera| Crambidae    |           | 599     | 248        |
|           | Sphingidae    |           | 0       | 1          |
|           | Cicadellidae  |           | 4       | 7          |
|           | Blissidae     |           | 3       | 2          |
| Heteroptera| Corixidae    |           | 1965    | 1697       |
|           | Rhyparochromidae |       | 2       | 1          |
|           | Miridae       |           | 92      | 5          |
|           | Ichneumonidae |           | 22      | 62         |
| Hymenoptera| Proctotrupidae|           | 1       | 0          |
|           | Braconidae    |           | 2       | 1          |
| Neuroptera| Chrysopidae   |           | 12      | 4          |
|           | Lauxaniidae   |           | 2       | 3          |
| Diptera   | Anthomyiidae  |           | 2       | 0          |
The order Heteroptera is represented in collections by five families of bugs and cicadas: Corixidae, Miridae, Rhyparochromidae, Blissidae and Cicadellidae. The quantitative predominance of hydrobionts is also explained by the abundance of habitats suitable for them and high ability of adults to be attracted to light sources.

All representatives of dipterans trapped in the species are species with noticeable daily activity, so their low abundance in the catch can be explained by an accidental hit.

Important research results include the obtained flight dynamics of a number of insect species (Figures 1-4). The information presented on these graphs is relevant only for a short period of research time, to obtain truly representative results requires a longer period of research.

| Family          | Count  |
|-----------------|--------|
| Sarcophagidae   | 0      |
| Orthoptera      | 3      |
| Odonatoptera    | 1      |
| Gryllidae       | 0      |
| Coenagrionidae  | 0      |

Figure 1. Dynamics of representatives’ number of various families of Coleoptera order attracted by conical light trap
Analysing the data in Figures 1 and 2 obtained during the research period reflects the fixation of peaks and a decrease in the activity of the adult species of the families Carabidae, Hydrophilidae, Staphilinidae and Heteroceridae belonging to the order Coleoptera. Moreover, the tested trap types showed the closest dynamics in the number of species of the families Heteroceridae and Hydrophilidae. Dynamics of the representatives’ number of the families Staphilinidae and Carabidae, obtained using various designs of light traps, had insignificant differences.

Trapping throughout the experiment of a complex of the same species and taxa of a higher rank allows us to conclude that the traps tested are highly attractive specifically for these insects. Of particular importance is the attractiveness of light traps for species recognized as the main pests of corn (cotton scoop, stem moth) (Figure 3.4), which, in the case of further confirmation of the obtained data, will allow us to recommend this method of controlling their abundance in agroecosystem of agricultural crops for widespread use.

Figure 2. Dynamics of representatives’ number of various families of Coleoptera order attracted by aspiration light trap.

Figure 3. Dynamics of representatives’ number of various families of Lepidoptera order attracted by conical light trap.
According to figures 3 and 4, the high efficiency of traps, especially conical ones, for eliminating scoops from agrocenosis is noticeable. Given the high ability of almost all Noctuidae representatives to migrate, it can be assumed that in the first days of the experiment a large part of the local scoop population was caught, since their number was noticeably lower than the initial one and was maintained either due to the emergence of new butterflies from pupae, or due to migrants. It is difficult to draw conclusions about the summer dynamics of the stem moth, since they are contradictory, possibly due to the short experimental period. In the course of further planned studies, these data are going to be adjusted.

Species of the Ichneumonidae family of the Hymenoptera order are more effectively attracted (or fixed in the insect receiver) by an aspiration trap, which is facilitated by its structural features and sizes of representatives of this family. Additional studies will make it possible to draw a conclusion about the effectiveness and feasibility of using this device to monitor the number of species representing the Ichneumonidae family, which play an important role in regulating the number of crop pests.

Bugs from the Corixidae family were collected by conical and aspiration light traps almost identically, with insignificant differences in the timing and number of insects attracted.

Tests of various designs of light traps conducted in 2018 make it possible to judge the low species diversity of insects in the corn agrocenosis by the readings of the Margalef index and the high abundance or high efficiency of attracting individual species, based on the values of the Berger-Parker dominance index. Moreover, a mathematical assessment of the significance of differences in the values of the indices for aspiration and conical traps showed the absence of significant differences with a probability of 99.9% (t<sub>stud</sub><sub>Fact.</sub>/t<sub>stud</sub><sub>Crit.</sub>, p> 99.9%) (table 3).

| Indices of | Conical | Aspiration | t<sub>stud</sub> Fact. | t<sub>stud</sub>Crit. |
|------------|---------|------------|----------------------|---------------------|
| Margalef   | 1.34±0.96 | 1.04±0.71  | 0.76                 | 3.105               |
| Berger-Parker | 0.90±0.11 | 0.92±0.09  | 0.35                 |                     |

4. Discussion and conclusions
The design features of each of the presented devices have a significant impact on the effectiveness of attracting insects.

Of the 27 families attracted by the light traps of the VNIIBZR design, species-representatives of 7 families (Elateridae, Noctuidae, Crambidae, Blissidae, Dermestidae, Pyralidae) are mainly harmful phytophages. Species of the families Carabidae, Ichneumonidae, Proctotrupidae, Braconidae, Chrysopidae are mainly entomophages, representing an entomofauna useful for humans and agrocenosis. The maximum number of attracted species belongs to the water beetles of the families.
Heteroceridae, Scitidae, Dytiscidae, Hydrophilidae, which can be attributed to indifferent species that have no effect on agroecosystems. Indifferent species also include representatives of the families Sphingidae, Corixidae, Rhyparochromidae, Lauxaniidae, Anthomyiidae, Sarcophagidae, Gryllidae, Coenagrionidae.

A comparative assessment of the effectiveness of attracting insects with various designs of light traps in corn agrocenosis shows mathematically significant differences in the number of attracted insects and the absence of significant differences in species diversity.

The presented designs of light traps based on super bright LEDs allow assessing biodiversity of insects in corn agrocenosis.

In order to mass capture pests of corn agrocenosis, the use of a conical light trap is more efficient. To maintain a useful entomofauna, it is necessary to use the separating structure of the insect receiver. It should be borne in mind that some pests, primarily representatives of Elateridae, also have small sizes (in catches from 1.5 to 6 mm in length and up to 2 mm in width), which will allow them to freely leave the insect when they enter it. In this regard, additional field studies are required to select the optimal cell size of the insect receiver.

Taking into account the revealed effectiveness of the light trap structures under consideration in the corn agrocenosis, it is planned to test them for faunal studies and mass capture of pests in other crops.

Acknowledgements
The studies were carried out in accordance with State Order No. 075-00376-19-00 of the Ministry of Science and Higher Education of the Russian Federation as part of research on the topic No. 0686-2019-0012.

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