EXPERIMENTAL INVESTIGATIONS OF THE OPERATION OF ELEMENTS OF THE EQUIPMENT FOR CASSETTE-LESS BREEDING OF THE GRAIN MOTH
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ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ РОБОТИ ЕЛЕМЕНТІВ КОМПЛЕКТУ ОБЛАДНАННЯ ДЛЯ РОЗВЕДЕННЯ ЗЕРНОВОЇ МОЛІ БЕЗ ВИКОРИСТАННЯ КАСЕТ

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DOI: https://doi.org/10.35633/inmateh-68-53

***Keywords:** grain moth, Trichogramma, cassette-less, technology, temperature, humidity, eggs, imago.*

ABSTRACT
Increasing the production efficiency of Trichogramma of guaranteed biological quality by creating promising biotechnologies, based on the optimization of the parameters of technobiocenosis, is an urgent scientific and practical problem. There have been developed elements of a set of equipment by the method of cassette-less breeding of the grain moths for industrial production of Trichogramma. Experimental and analytical studies were carried out of the impact of the main biological indicators upon the quality of production of an entomological preparation of Trichogramma. The impact of the main factors of technocenosis upon the viability and productivity of the grain moths has been studied by using a cassette-less production technology. The developed technological scheme for cassette-less cultivation of the grain moth and the use of recommendations for industrial production of Trichogramma will increase the output of biolaboratories by 10-15% while obtaining a Trichogramma of guaranteed biological quality.

АНОТАЦІЯ
Розроблено елементи комплекту обладнання методом розведення зернової молі без використання касет для промислового виробництва трихограми. Проведено експериментальні та аналітичні дослідження впливу основних біологічних показників на якість виробництва ентомологічного препарату трихограми. Досліджено вплив основних факторів техноценозу на життєздатність та продуктивність зернової молі під час використання технології виробництва без використання касет. Розроблена технологічна схема для розведення зернової молі без використання касет та дотримання рекомендацій щодо промислового виробництва трихограми дозволять збільшити на 10-15% продуктивність біолабораторій, при цьому буде отримана трихограма гарантованої біологічної якості.

INTRODUCTION
One of the effective ways of using the biological method of protecting plants, mainly the field and vegetable crops, is the use of local species of entomophages by the method of their seasonal colonization. It is carried out by releasing artificially bred individuals of a species, common for the place of application. Most massively used in Ukraine and other European countries is the egg-eater Trichogramma. An increase in the scale and efficiency of the use of Trichogramma can be achieved by the development and implementation of more modern technologies, based on the creation of a unified set, characterized by balanced mechanization, decrease in the amount of manual labour, reduction in the cost and decrease in the technological operations, used during the production cycle *(Rudyk et al., 2013; Belchenko et al., 2000; Buse et al., 2015; Krutyakova et al., 2020*).

As a result of analysis of the existing technologies, the following urgent tasks were identified: – improvement of technology and technical means throughout the entire cycle of production of grain moth and Trichogramma; – maximum reduction in the number of modifications of the equipment, used in the production cycle; – solution of a problem of efficient layout of laboratories of various production capacities; – creation of an element base of machines, instruments and devices to ensure resuscitation of the network of biofactories and biolaboratories that existed before. Elements of a set of equipment were created by the method of cassette-less breeding of the grain moth for industrial production of Trichogramma *(Marsh & Trenham, 2008)*. This method provides for a cycle of technological operations (infection, maintenance, release and collection of the imago) in a single apparatus, which allows to reduce the number of technological operations, the labour costs, and dust emission. Thus cultivation of the grain moths in a large quantity makes it possible to abandon the traditional cassette-box technology and move on to building entomological production facilities of a new generation *(Ghosh, Haldar & Mandal, 2014)*.

Preliminary research showed that introduction of a cassette-less technology for breeding the grain moths and Trichogramma, in contrast to the existing equipment, will increase the level of mechanization and automation of the technological operations by up to 20%, reducing the metal consumption of the created equipment by up to 15% *(Morales-Ramos, Rojas, & Shapiro-Ilan, 2014; Dortel et al., 2013, Marus et al., 2022)*.

The aim of the work is to study the dynamics of the grain moth cultivation using a set of equipment for the production of Trichogramma according to a cassette-less technology.

MATERIALS AND METHODS

The installation for cassette-less breeding of the grain moth allows one to combine in a single volume the technological processes, such as infection of the grain, the development of caterpillars, pupae and emergence of the imago. The installation allows mechanization of the processes of «loading – unloading» the grain, its mixing and ventilation. It consists of a cylindrical container with vertical perforated tubes, located inside for the moth exit and the grain cooling, a mixing device in the form of a driven auger, and a fan, which are switched on by signals from a temperature control sensor, located in the working volume (Fig. 1). The traditional method consists in infecting the grain in open pallets, manually mixing it, which are closed with tight lids before the butterflies leave and turn into cassettes. The rotation speed of the screw was 24 rpm, atmospheric pressure was maintained inside.

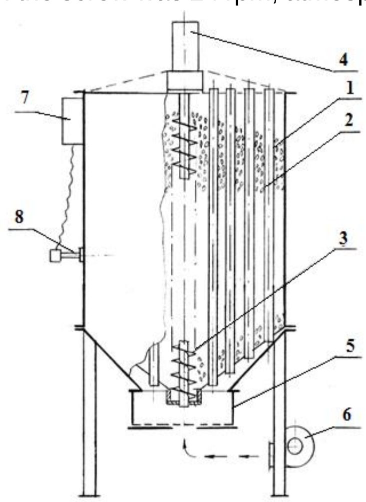

Fig. 1 - A scheme of the installation for cassette-less breeding of the grain moth

1 – motor-reducer, 2 – moth conduit, 3 – auger, 4 – electric drive, 5 – receiving cage, 6 – fan, 7 – temperature controller, 8 – temperature sensor

To ensure the technological temperature and humidity parameters of the process, as well as to synchronize the output of the imago, mechanical mixing and ventilation of the grain are provided. The capacity of the installation is 1.5 kg of the grain moth eggs per cycle. The experimental samples of the technological equipment ensure maintenance of the microclimate parameters for breeding Trichogramma by the method of intensive air exchange between the multiplier and the room where the pre-set microclimate parameters are maintained within the range of temperature t from 22 to 28° C and relative humidity φ from 75 to 85%. In the production area itself, it is planned to use a displacement ventilation scheme. Air humidification is effected by using water vapour. A high degree of synchrony in the Trichogramma development is achieved by ensuring uniform distribution of the fields of abiotic factors that characterize the technocenosis in the working volume: the temperature, relative humidity, illumination, and so on *(Isaev et al., 2008)*.

To ensure uniform distribution of the microclimate parameters in the container itself, as well as to remove the volatile metabolites, a constant movement of the air mass and a high intensity of air exchange are maintained. The air movement is directed along the surface of the plates with the host eggs. The excretion of metabolites makes it possible to reduce the stress level of the individuals due to the increased density of population retention, as well as to prevent the development of pathogenic microflora in the working area. Illumination of low intensity and uniform over the entire area of the working zone contributes to uniform distribution of the entomophagy individuals over the working surface.

The design of the working area suggests a possibility to select the Trichogramma individuals by the search and flight activity. That is, there is excluded a possibility of direct transfer of the Trichogramma specimens from the container for the exit of the imago directly into the plates with the laid eggs of the host. To this end, the plates are placed in such a way that they do not have direct contact with the walls of the main chamber. Considering that the equipment is aimed at the use of an entomophage in the industrial production, particular attention was paid to the convenience of its use. So the maintenance of the working area (introduction of the prepared plates with the host eggs into the main chamber, introduction of the Trichogramma of the parent generation, extraction of the biomaterial, cleaning of the working area from contamination) is carried out through the side wall of the main chamber. The cycle of the technological process is carried out within 42 – 50 days.

The prepared grain moth eggs, weighing 1 g per 1 kg of grain, are introduced into the installation by evenly scattering them over the surface of the grain cone. On the surface of the grain cone two control cards are placed with 10 mg of the grain moth eggs on each in order to monitor the regeneration dynamics of the larvae and establish the starting date of the grain infection, the date of which should coincide with the rebirth of at least 80% of the larvae.

For 5 days the moisture content of the grain is determined (if necessary, bringing it to the nominal value), and the auger is turned on. When controlling t of grain, the measurement is made at 5 points of the grain chamber, and the average value is determined. After 15 days, when the larvae pass over into the pupa, the percentage of the grain infection is determined. During the period of the imago emergence it is continued to control t and the grain moisture, which are decisive for the technological cycle of the grain moth production; ventilation is continued without mixing.

The development of Trichogramma begins with the application of a feeder egg to the working plates, after which a block of the plate is placed in the multiplier container and a revived Trichogramma is introduced in a definite amount. Within two days the infection process should take place under hygrothermal conditions that are optimal for specific types of Trichogramma and a corresponding geographical area. To prepare the trichogram for a diapause induction, the general quality indicators of the parental generation of Trichogramma are preliminarily assessed: the number of parasitized eggs, the rebirth, sex index.

RESULTS AND DISCUSSION

The conducted laboratory investigations of the cycle of cassette-less breeding of the grain moth made it possible to determine the dynamics of changes in the temperature of the grain and air (Fig. 2), and relative humidity (Fig. 3). The grain temperature during the period of the grain moth colonization (1-7 days) increases quite smoothly and reaches approximately 28° C. At the same time the air temperature fluctuates slightly at the level of 25° C. The relative humidity of the air in the room remained within the regulated limits ($\varphi \approx 80\%$), the air temperature (Δt) increased by more than 8° C. This difference may reach 12° C, but during this period, in addition to the fan, the auger also works, which makes it possible to keep the temperature of the grain within the limits stipulated by the regulations. The relative humidity of the air during this period decreases, which is caused by an increase in the temperature of the room *(Bespalov, Belchenko & Leshishak, 2015)*.

In our experiment φ decreased below the regulated value by 5%. The cassette-less grain moth breeding equipment is distinguished by a more uniform temperature field of the grain in the working area, determined by the following components: blowing air with optimal temperature through the moth conduits, evenly spaced over the volume, for growing the grain moths, which ensures convective heat removal; a significant reduction in the amount of grain in the boundary layer, in contrast to the cassette-box technology; by mixing the nutrient medium with an auger mechanism, which ensures regular movement of each individual grain both in the vertical and horizontal directions. The most stressful period are the first five days of obtaining the imago (Fig. 4).

Its implementation is complicated by the fact that the screw mechanism does not work, but Δt gradually decreases from the maximum.

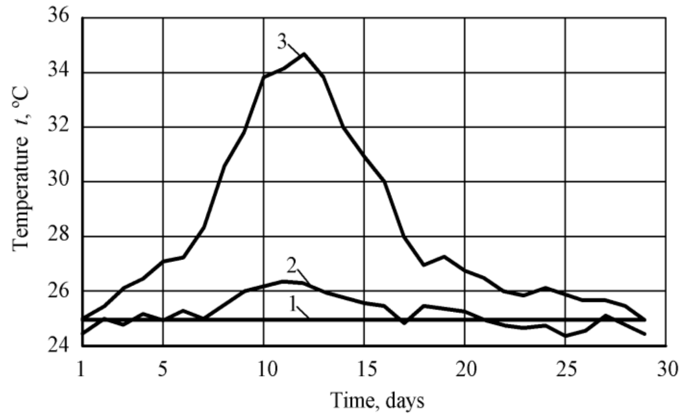

Fig. 2 - Dynamics of the air and grain temperature changes during the grain moth breeding cycle

1 – set temperature; 2 – air temperature; 3 – grain temperature

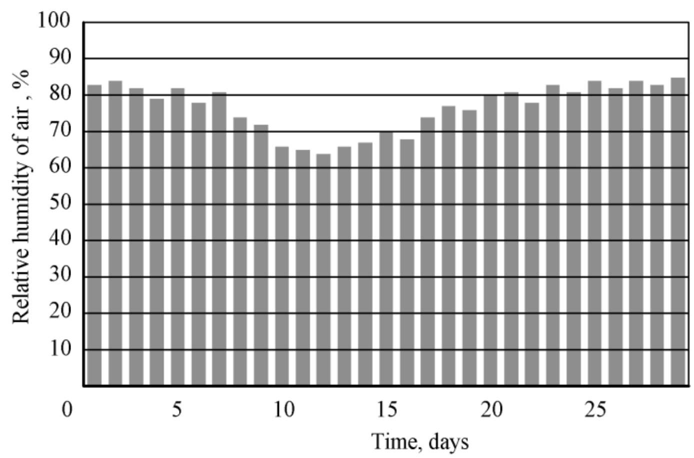

Fig. 3 - Dynamics of changes in the relative humidity of the air, during grain moth breeding cycle

Processing of the results obtained according to the output of the imago (*y*, *r*) made it possible to obtain an equation in the form of a polynomial of the 6th degree:

– for the modular kit:

$$y = 0.0003 \cdot x^6 - 0.025 \cdot x^5 - 0.9584 \cdot x^4 - 17.01 \cdot x^3 + 137.44 \cdot x^2 - 379.47 \cdot x + 383.33 \quad (1)$$

– for the equipment of the cassette-less production:

$$y = 4 - 0.5 \cdot x^6 - 0.0042 \cdot x^5 + 0.1591 \cdot x^4 - 3.0715 \cdot x^3 + 27.887 \cdot x^2 - 64.053 \cdot x + 106.39 \quad (2)$$

Where: y – mass (weight) of the imago of the grain moth, g;

x – term, days.

The approximation confidence factor (R^2), showing the degree of compliance of the trend model with the original data, is: – for the modular kit 0.9067; – for the equipment of the cassette-less production 0.9806. It can be concluded that the obtained models correspond to the natural experiment with a satisfactory error.

The conducted studies made it possible to analyse the dynamics of obtaining eggs with various technologies of breeding the grain moths (Fig. 5). The release of the imago during the cassette-free breeding takes place in a shorter period of time *(Belchenko & Pishchanska, 2018)*.

Processing the results before obtaining the egg (y, g) made it possible to obtain an equation in the form of polynomials of the 6th degree:

– for the modular kit:

$$y = -2 - 0.5 \cdot x^6 + 0.0015 \cdot x^5 - 0.0462 \cdot x^4 + 0.5718 \cdot x^3 - 2.7717 \cdot x^2 + 12.368 \cdot x - 7.5513 \quad (3)$$

$R^2 = 0.9954$;

– for the equipment of the cassette-less production:

$$y = 3 - 0.5 \cdot x^6 - 0.0029 \cdot x^5 + 0.1184 \cdot x^4 - 2.2817 \cdot x^3 + 19.508 \cdot x^2 - 51.037 \cdot x + 46.834 \quad (4)$$

$R^2 = 0.963$;

Where: y – mass of the eggs of the grain moth, g;

x – term, days;

R^2 – the approximation confidence factor.

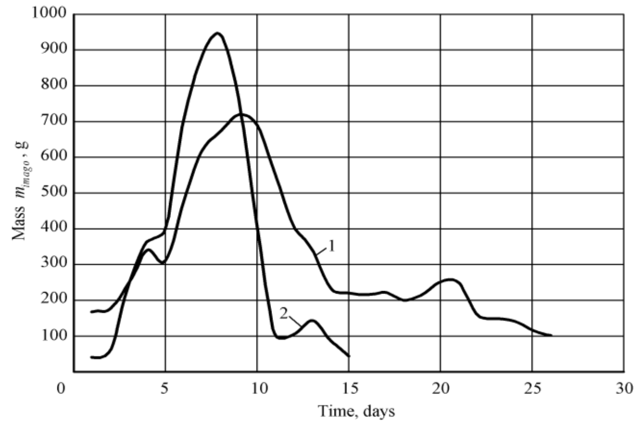

Fig. 4 - Dynamics of grain moth imago production, using a cassette and a cassette-less technologies

1 – modular kit; 2 – installation of cassette-less breeding of grain moth

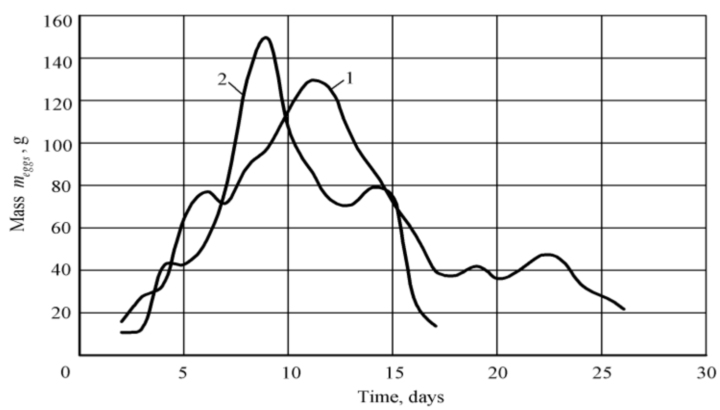

Fig. 5 - Dynamics of the grain moth egg production, using a cassette and a cassette-less technologies

1 – modular kit; 2 – installation of cassette-less breeding of grain moth

When growing the grain moths in a large volume, 80% of the egg production was achieved in 17 days, and the remaining 20% in the following 7 days. Taking into account that the production of the grain moth is seasonal, it is advisable to stop the cycle on the 17-18th day and, at the expense of the time saved, increase the number of cycles per season. This approach will improve the efficiency of the equipment used. The resulting dependencies can be used to determine the busy time of the equipment used.

Approbation was carried out – the equipment is able to work, and its use ensures an increase in the output of the semi-automated and mechanized technological operations up to 23%, a decrease in the metal consumption up to 14%, compared to the existing one. The results were also implemented – an experimental sample of a set of equipment, based on the cassette-less breeding of the grain moth for industrial breeding of Trichogramma was created.

CONCLUSIONS

1. The cassette-less grain moth breeding equipment is distinguished by a more uniform temperature field of the grain in the working area, determined by the following components: blowing air with an optimal temperature for breeding the grain moths (t = 20-22° C and φ = 70-80%) through the moth conduits, evenly spaced over the volume, which ensures convective heat removal; reduction in the amount of grain which is in the boundary layer with the air of the working area by almost 3 times, compared to the cassette-box technology; mixing of the nutrient medium by an auger mechanism, which ensures regular movement of each individual grain both in a vertical and a horizontal direction.

2. The industrial cycle of breeding the grain moths in a large volume can be reduced by 10-12 days, in comparison with the cassette technology, while receiving 80% of the total amount of the egg production. Taking into account that the grain moth production is seasonal, it is advisable to stop the cycle on the 17th-18th day of the imago emergence and, at this expense, to increase the number of cycles per season. The shortened technological cycle will increase the efficiency of the equipment used by 20%.

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