EXPERIMENTAL STUDY OF LARVAE CAGE AREA IMPACT ON PRODUCTIVITY IN GREEN LACEWING INDUSTRIAL-SCALE REARING

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Abstract. The article analyses the experimental results of the cage area effect on green lacewing productivity. The tests were made under the conditions of the complete green lacewing (*Chrysoperla carnea*) rearing process on the base of the Engineering and Technological Institute “Biotekhnika” of NAAS of Ukraine in partnership with the the Latvia University of Life Sciences and Technologies. The research was focused on the correlation between the larvae cage productivity and its inner area. Four cage types with the same design and different areas were studied in the experiments. The set of experiments includes parallel insect rearing in three cages of each type. The specific productivity in cocoons·cm^{-2} was chosen as the main cage efficiency parameter. The analyses showed the productivity reduction with the cage area increasing. However, in the range of the cage area of 550-950 cm^2 the average productivity kept constant of 0.64 cocoons·cm^{-2}. The detected interval could be used for cage manufacturing and further equipment set forming with increased economic efficiency. The cage number in such equipment set would be 1.5 times less in comparison to the basic one for the same set productivity. Therefore, the equipment set manufacturing and maintenance costs would be decreased.

Keywords*:* green lacewing, rearing, larvae cage, productivity, area increase.

Introduction

Green lacewing *Chrysoperla carnea* (Stephens) is an effective entomophage. It is widely used for biological control of harmful insects in the world. Mass rearing of green lacewings is based on various technologies and equipment, the development of which has been and remains an urgent task [1; 2].

The equipment set for green lacewing mass rearing and the corresponding technology were developed at the Engineering and Technological Institute “Biotekhnika” of NAAS of Ukraine in 2008 [3; 4]. The developed cage design permitted high survival of green lacewing larvae and pupae, and also allowed to proceed from individual keeping to group keeping of larvae. The equipment set included the cages 25×25 cm and 1.5 cm of height. In this paper we named such cage – the basic design cage or simply – the basic cage. Further developments of the equipment set for green lacewing rearing made at “Biotekhnika” were focused on technical and economic efficiency increasing on the basis of system design methods [5]. In particular, the efficiency evaluation practicability based on the production cost of cages and boxes was validated [6; 7]. Also, it was shown that the production cost would be minimal at the maximum cage areas.

The green lacewing mass rearing technology is grounded on two main types of cages: larvae cage (CL) and cage for imago. The developed model of technical and economic efficiency [8] allowed the larvae cage size validation and further creation of cages 25×50 cm. A new technological equipment set was designed on the base of such cages in 2020 [9].

Long-term operational testing of 25×50 cm cages identified some disadvantages in comparison with the basic cage 25×25 cm created in 2008. First of all, its rectangular shape with an aspect ratio of 1:2 proved to be very inconvenient in operation and also it complicated the design of racks and boxes. Therefore, it was decided to return to the square cage shape and to conduct experimental studies for the optimal cage size determination.

The aim of the study is to determine the dependence of the productivity on the area of larval cages and to justify the design of cages with increased technical and economic efficiency.

Materials and methods

The experimentation of the cage area impact on the productivity was carried out in the conditions of the full technological process of green lacewing rearing in accordance with the technological regulations. The region of the origin of green lacewing used in the study was Odesa Oblast, Ukraine.

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Natural habitat of insects was herbaceous plants. Insect useful characteristics maintenance was made by inbreeding. The inbreeding line of green lacewing was created and maintained at the Engineering and Technological Institute “Biotekhnika” of NAAS of Ukraine.

The similar design cages with four different areas were used for the single-factor experiment (Table 1, Fig. 1). There were four sets of experiments for each test. Every set of experiments included parallel insect rearing in three cages of each size. Green lacewing eggs were put into the cage. Larvae were hatched from eggs, and then pupated. Grain moth (*Sitotroga cerealella*) eggs were used for lacewing feeding in our rearing technology.

Table 1

Size of the cages for larvae green lacewing rearing (in horizontal plane)

Cage type	**External sizes, mm**	**Internal sizes, mm**	**Usable area, cm^2**	**Area change factor**
1CL	180×180	170×170	289	0.502
2CL	250×250	240×240	576	1.000
3CL	310×310	300×300	900	1.563
4CL	360×360	350×350	1225	2.127

The cage design was developed on the ground of modelling with the use of biomaterial with respect to the results of our previous work [10]. All cages were made from acrylic glass 5 mm thick. The cage bottoms were sieve clothed for air change maintenance in the inner space by ambient air input. Two or three supports provided the gap of 15-18 mm between the bottom and the surface on which the cage stands. They ensure ambient air inlet into the cage through the bottom. The cage covers were made form 10 mm plastic plates. They had the same dimensions as the external size of the cages (Table 1).

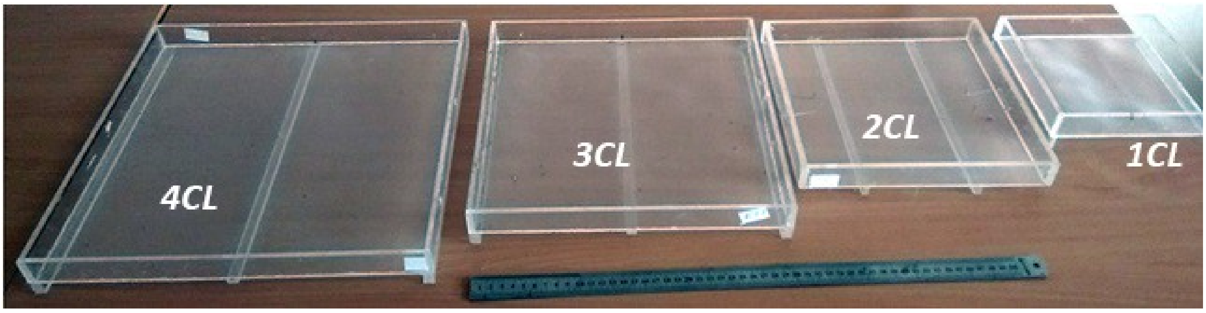

Fig. 1. **Larvae green lacewing cage types used in the study**

In the previous works [10] we demonstrated that the determining condition for modelling of entomophage rearing processes was the invariability of the insect layer height as it determined the height of the cage. The surface density of insects at the beginning of the life cycle in the cage also played an important role.

The green lacewing larvae cage height, which was the space height inside the cage, was 15 mm for all cage types. The number of lacewing eggs (Table 2) and the feed for their larvae – grain moth eggs (Table 3) were calculated on the basis of regulated surface insect density in the cage. Other abiotic parameters that should be kept unchanged according to the technological regulations were the air temperature and humidity, and illumination inside the cage.

Table 2

Norm of green lacewing egg cage input

Cage type	**Norm of egg cage input**	
	pcs	**g**
1CL	3450	0.21
2CL	6900	0.63
3CL	10330	0.63
4CL	13770	0.84
Mass of 1000 green lacewing eggs is 0.061 g		

Table 3

Norm of grain moth egg input for green lacewing larvae feeding

Cage type	Norm of egg cage input by days of rearing, g				
	1	3	5	7	9
1CL	0.378	0.888	2.069	4.825	4.452
2CL	0.756	1.770	4.122	9.612	8.868
3CL	1.182	2.766	6.443	15.023	13.860
4CL	1.608	3.765	8.767	20.440	18.862
Mass of 1000 grain moth eggs is 0.0191 g					

The main technological indicator for the larvae cage was the specific area productivity W, cocoons·cm^{-2} [10] (hereinafter referred to as productivity), which was equal to the ratio of the obtained cocoons to the cage usable area S, cm^2. Consequently, the experiment task was determination of the correlation:

$$W = f(S), \tag{1}$$

The results were presented as:

$$W = W_C \pm \Delta W, \tag{2}$$

where W_C – arithmetic average (hereinafter referred to as average) cage productivity;
ΔW – confidence interval for probability 0.95.

Experimental data processing was made according to known methods [11; 12].

Results and discussion

The study was conducted by realization of the full technological process of green lacewing rearing according to the technological regulations. The study consisted of three tests. Each test included four sets of experiments made in parallel. Every set of experiments was made in three cages of each type simultaneously. Every test lasted about 40 days. They were conducted consecutively in time during October 2021 – February 2022. The cage representation during the experiments is depicted in Fig. 2. The experimental data processed by equations (1), (2) are presented in Fig. 3.

Fig. 2. **Cages with covers (left) and green lacewing imago (right) inside the cage in the experiments**

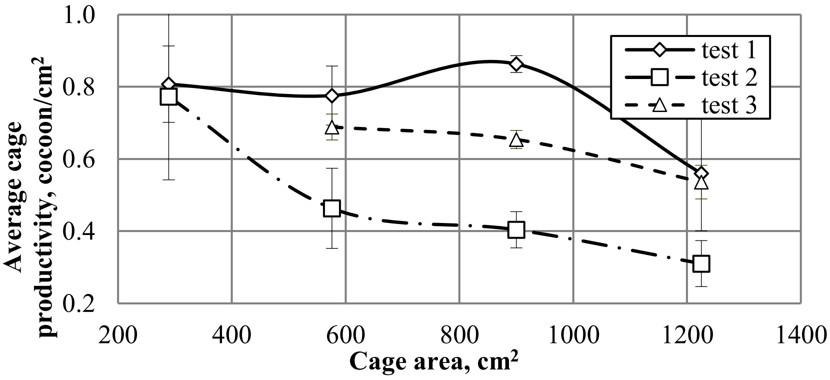

Fig. 3. **Dependence of larvae cage average productivity on its area**

There are the average cage productivity W_C (points) and confidence interval ΔW (vertical lines) for four cage types with different usable areas S in Fig. 3. The average productivity was calculated for every set of experiments (points along the vertical lines). The lines connecting the points and forming the diagram were drawn conventionally. Their main purpose was to simplify the visual perception of the tests.

The significant differences among the tests are defined by two main factors. The first one was the impact of the time of the year on the insect life cycle, and the second consists in using of grain moth eggs with different quality for lacewings feeding. However, the general character of the cage area effect on the productivity is well defined. Cage area increasing led to the productivity reduction through all three tests (Fig. 3). This is caused by cannibalism of green lacewing larvae. That is why most laboratory and industrial equipment use individual housing of green lacewing larvae.

Further averaging of three tests consecutive in time was made. The results are shown in Table 4 and Fig. 4.

Table 4

Averaging of tests with larval cages

Cage type	Cage area, cm^2	Area change factor	Average specific cage productivity, $cocoons \cdot cm^{-2}$	Confidence interval, $cocoons \cdot cm^{-2}$
1CL	289	0.502	0.790	0.129
2CL	576	1.000	0.664	0.102
3CL	900	1.563	0.640	0.131
4CL	1225	2.127	0.469	0.097

The lines connecting the points in Fig. 4 were drawn conventionally for simplification of the experiment visual perception.

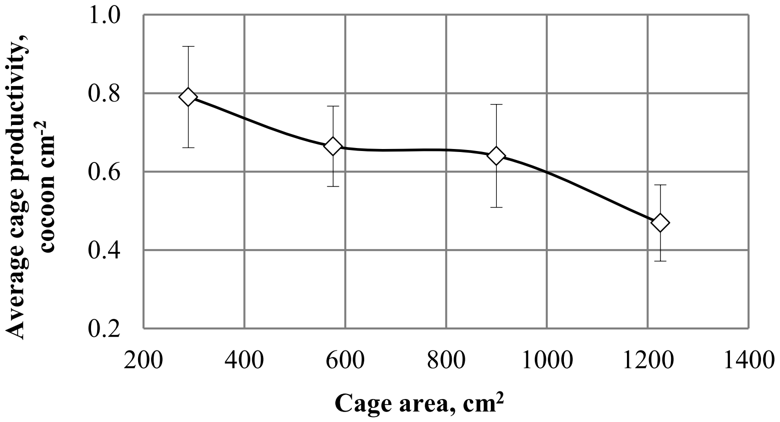

Fig. 4. **Averaging over three tests of the dependence between the productivity and the cage area for green lacewing larvae rearing**

Data analysis showed that in the interval of the cage area of 550-950 cm^2 the average productivity can be considered as a constant value of 0.64 $cocoons \cdot cm^{-2}$ with the confidence interval of 0.13 $cocoons \cdot cm^{-2}$. Thus, the larvae cage area could be increased 1.45-1.6 times in comparison with the basic cage (2CL) for keeping the set productivity. At the same time, such cage area increasing allows to reduce their number in the set by about 1.5 times. This will enhance the economic effect due to the cage manufacturing charge reduction and production facility maintenance cost reduction.

Conclusions

1. The one-factor experiment with green lacewing larvae cages of different area showed that the specific productivity of the cage in cocoons decreased with the cage area increasing.
2. It was found that average productivity for cages with the area of 550-950 cm^2 could be considered as constant. Due to this reason larvae cage area could be increased 1.45-1.6 times in comparison

with the basic cage of 25×25 cm and ensure constant productivity of the technological equipment set with a reduction in the number of cages by about 1.5 times.

3. Economic efficiency could be increased due to the cage set manufacturing charge reduction, as well as production facility maintenance cost reduction.

Author contributions

Conceptualization, I.B.; methodology, V.Y. and I.B.; validation, A.A. and V.B.; formal analysis, V.B.; investigation, I.B., V.K. V.Y and V.Ba.; data curation, A.A., V.B.; writing – original draft preparation, A.R.; writing – review and editing, A.A. and A.R.; visualization, V.Y.; project administration, V.B.; funding acquisition, A.R. All authors have read and agreed to the published version of the manuscript.

References

[1] Cohen A.C., Nordlund D.A., Smith R.A. Mass rearing of entomophagous insects and predaceous mites: are the bottlenecks biological, engineering, economic, or cultural. Biocontrol News and Information. 1999. Vol 20. No. 3. 85N-90N.

[2] Adhikari J., Karki A., Gautam B. Mass rearing techniques of green lacewings Chrysoperla carnea Stephens – A Review. Journal of Agricultural Science and Technology. 2020. Vol 9, No 2.

[3] Sapozhnykova M.M., Bilousov Y.V., Belchenko M.V. The technology of larvae feeding of green lacewing Chrysoperla affinis Steph. Bulletin of Agrarian Science of the Southern Region: interdepartmental thematic scientific collection: SMIL, 2012. Is. 12-13. pp. 139-150 (In Ukrainian).

[4] Krutyakova V. Effective technological equipment for mass production of entomophagous insects and mites used for biological control. Journal of Agricultural Science and Technology B 2017. Vol. 7. pp. 179-186.

[5] Jones J.C. Design Methods. John Wiley and Sons Ltd. 1982.

[6] Bespalov I., Hodorchuk V. Fundamentals of engineering design of technological complexes for industrial production of entomophages. Plant protection in traditional and ecological agriculture: Proceedings of the international scientific conference. Institute of Genetics, Physiology and Plant Protection, Chisinau, 2018, pp. 163-167.

[7] Krutiakova V., Bespalov I., Bulgakov V., Viesturs D. Engineering design of industrial production of golden-eyed lacewings (L. chrysoperla carnea steph) in the programs of biological protection of plants. Engineering for rural development. 2019. Vol.18. pp.278-283.

[8] Krutyakova V.I. Technical and economic analysis of project solutions of the technological complex of entomophages industrial production. Bulletin of Agrarian Science. 2019. No. 11 (800). pp. 75-80. (In Ukrainian)

[9] Krutyakova V., Bespalov I., Rucins A., Bulgakov V. Determination of technical and economic efficiency of equipment for mass rearing of entomophages. Engineering for rural development, Jelgava, 20. 2020. 1162.

[10] Bespalov I.M., Khodorchuk V.Y. Scaling of insect cages in the creation of technological complexes for the entomophages industrial production. IOBS EPRS information bulletin No. 53. Odesa: TPP, 2018. pp. 40-49 (In Ukrainian).

[11] Berk K.N., Carey P. Data analysis with Microsoft® Excel. 2010, 2004 Brooks/Cole, Cengage Learning.

[12] Carlberg C. Statistical analysis. Microsoft® Excel® 2013. GUE 800 E. 96th Street, Indianapolis, Indiana 46240.