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Method of development of bioengineering complexes of production of entomo-cultures

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The purpose. To develop methods of designing bioengineering complexes of production of entomo-cultures. **Methods.** Analytical, systematized search, structurally-parametrical and intellectual. **Results.** The frame of bioengineering complex of production of entomo-cultures is specified. The structurally-parametrical complex of evaluation test of trichogramma is developed. On the basis of the theory of indistinct flocks the expert system of evaluation test of grain moth (*Sitotroga cerealella Oliv*), hexapod-host of entomophage Trichogramma is prepared. **Conclusions.** Structural and intellectual methods are developed of designing bioengineering complexes of production of entomo-cultures. That can be beneficial in a subsystem of decision-making at building control systems over the production of entomophages by criterion of quality. Application of the theory of indistinct flocks allows tracking influence of parameters on quality indexes of entomo-cultures in conditions of the limited entrance data, to save time for acceptance of necessary decisions.

Key words: *bioengineering complex, entomo-culture, quality, indistinct flocks.*

Introduction. Improvement of the methods of developing bioengineering complexes for the production of entomocultures is called for the necessity of obtaining in the technocenose an entomological product of guaranteed quality with a view to its further application in agrocenoses, which significantly reduces the amount of chemical plant protection products.

At present, the study of entomoculture bioengineering complexes relates to:

- substantiation and calculation of insect living volumes in biotechnological systems for the production of entomologic drugs [1];
- development of climatic complexes for experiments with biological objects [2];
- application of artificial diets, feeding of adult stages of entomophages, preservation of insect cultures in laboratory conditions [3, 4, 5];
- use of mathematical, information methods of analysis and modeling of iterative technological processes [6];
- creation of complex systems of mass production of entomocultures [7];
- development of technological equipment for industrial breeding of entomocultures [8].

The purpose. Development of methods for designing bioengineering complexes for the production of culture insects.

Materials and methods of research. The object of the research is the production of the *Trichogramma* entomophage, which is used to regulate the number of Lepidoptera (various types of Noctuidae, Pieris, Pyralidae, Tortricidae and Cydia, Geometridae, Lasiocampidae, etc.) on cereals, leguminous plants, technical and vegetable crops, perennial grasses, in the garden etc. [9]. The materials for the work were the results of experimental studies conducted by scientists Engineering and technological Institute “Biotechnics” NAAS during the implementation of the research work no. 43.03 / 015 "Create universal information and measurement systems for controlling the technological processes of breeding entomophages, acariphagus and phytophagous". Methods of research - analytical, systematic search of structural-parametric and intelligent.

Results. Bioengineering complex of production of entomocultures (Figure 1) is a biotechnical system which is inherent: in connectivity, integrity, integrativity (emergence), organization, the presence of a cycle of existence [10].

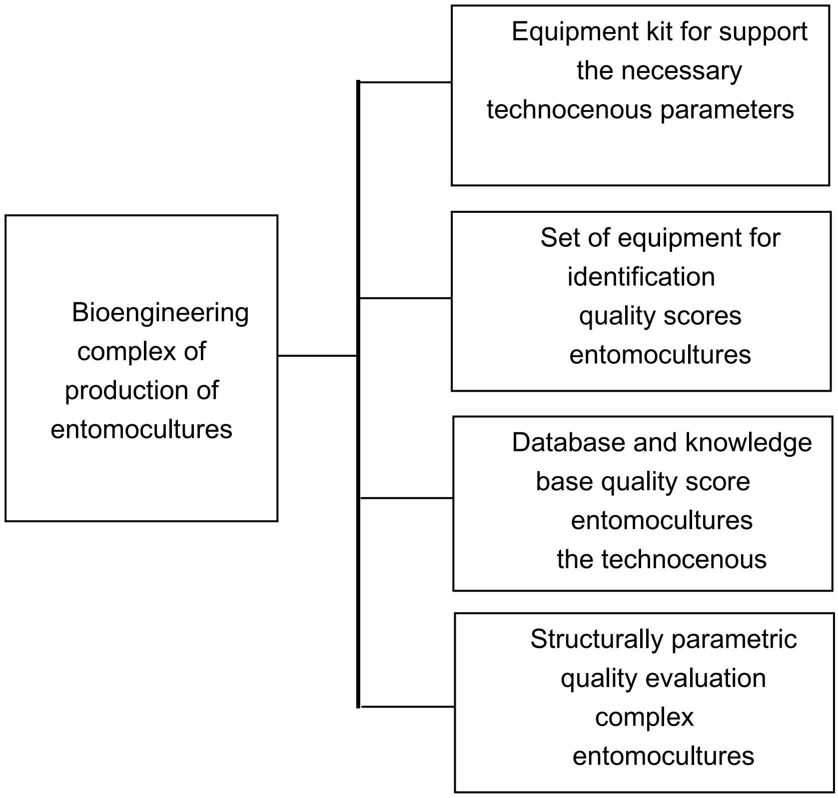
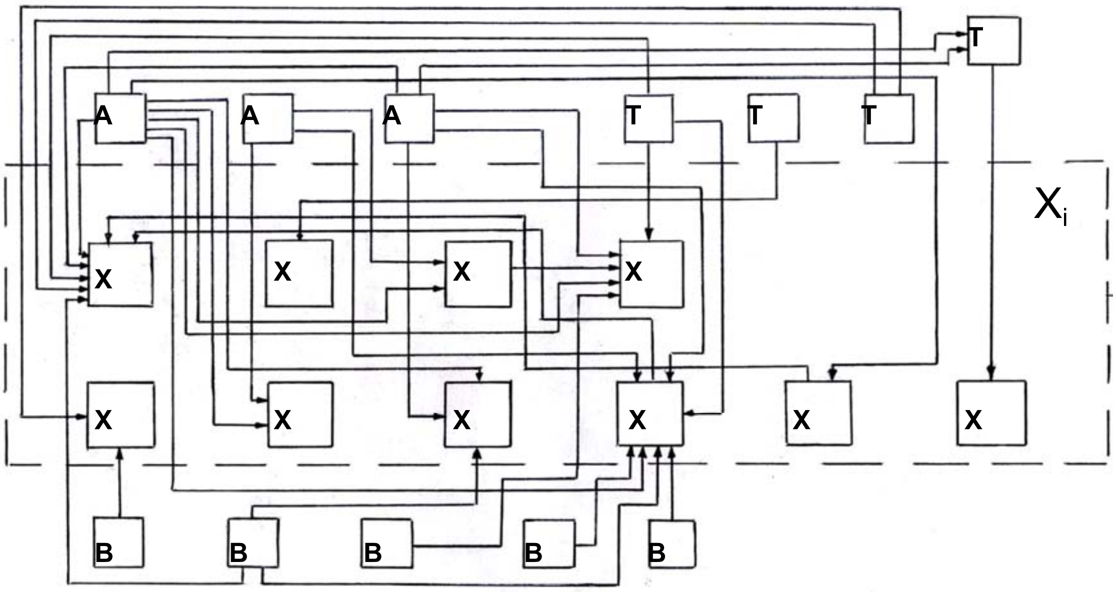


Fig. 1 The structure of the bioengineering complex for the production of entomocultures

According to the results of theoretical and years of experimental research conducted in ETI "Biotechnics", developed a structural-parametric complex of estimation of quality of *Trichogramma* (Figure 2) which reflects the dependence of biological parameters of parasitoid quality on a large number of factors (abiotic, biotic, technological); while the formalization of dependencies is most often absent. When developing systems for optimal management of the quality of entomological products, there is a question of using these results, which can be presented in the form of databases and knowledge bases. To approximate the dependence of the quality indices of entomocultures on a combination of factors, it is possible to use one of the methods of artificial intelligence - the theory of fuzzy sets - due to the peculiarities of industrial production of entomocultures, which is characterized by stochastic (ambiguous behavior of the biological component by the influence of factors of influence) and the effect of disturbing factors (a sharp change in temperature and relative humidity of the external environment, the termination of electricity supply).



X_i (X_1-X_{10}) – Biological indexes quality of Trichogramma:

X_1 – parasitic
X_2 – emergence
X_3 – expectancy of females
X_4 – fertility
X_5 – sex index
X_6 – physical activity
X_7 – duration of development of *Trichogramma*
X_8 - search capability
X_9 – the rate of infection of eggs of insect - hosts
X_{10} – viability

T_1-T_4 – Technological factors:

T_1 – duration of dilution on one host
T_2 – shelf life of Trichogramma
T_3 – shelf life of eggs of insect – hosts
T_4 – introduction into diapause and exit from it

B_1-B_5 – Biotic factors:

B_1 – age of eggs of host insects
B_2 – тype of insect host
B_3 – size of insect host eggs
B_4 – density of eggs of insect hosts
B_5 – degree of presence in the plant of attractants

A_1-A_3 – Abiotic factors:

A_1 – air temperature
A_2 – relative humidity air
A_3 – photoperiod (illumination)

Fig. 2 Structural-parametric complex of estimation of quality of Trichogramma

Using the MATLAB program and the Mamdani-type fuzzy inference algorithm, an expert system for assessing the quality of grain moth (*Sitotroga cerealella Oliv.*), an insect host of the entomophage *Trichogramma*, has been prepared. The input parameters of the developed system are (Table 1): X_1 - air temperature, °C and X_2 - relative humidity air, % in the area of insect development; output: Y_1 – infestation of the grain *Sitotroga cerealella Oliv.* %; Y_2 – duration of development of *Sitotroga cerealella Oliv.*, days; Y_3 - weight of eggs of *Sitotroga cerealella Oliv.*, g / kg of barley grain.

The peculiarity of the fuzzy system lies in the fact that it is possible to organize management of biotechnological processes in the form of dialogue with an expert, since the linguistic rules of the fuzzy knowledge base are written in the form of the expressions "if - then".

Table 1 - Data for knowledge bases the expert system

Input and output variables parameters	Input and range of output parameters	Term sets	Linguistic assessment of parameters	The type and parameters membership function
X_1, °C	22-28	AX1	Lower temperature limit	Gaussmf [1,019; 22]
		BX1	Average temperature limit	Gaussmf [1,019; 25]
		CX1	Upper temperature limit	Gaussmf [1,019; 28]
X_2, %	83-88	AX2	Lower humidity limit	Gaussmf [0,8495; 83]
		CX2	Upper humidity limit	Gaussmf [0,8495; 88]
Y_1, %	85-89	AY1	Standard infestation	Gaussmf [0,6795; 85]
		CY1	High infestation	Gaussmf [0,6795; 89]
Y_2, days	28-36	AY2	Short duration	Gaussmf [1,665; 28]
		CY2	Long duration	Gaussmf [1,665; 36]
Y_3, g / kg of barley grain	7-10	AY3	Low weight eggs	Gaussmf [0,43; 7]
		CY3	Standard weight eggs	Gaussmf [0,43; 10]

In tabl. 2 shows the knowledge base of the expert system for assessing the quality of *Sitotroga cerealella Oliv.*; every row of tabl. 2 corresponds to one rule: if X_1 = «Lower temperature limit» i X_2 = «Lower humidity limit», то Y_1 = «High infestation» i Y_2 = «Long duration» i Y_3 = «Standard weight eggs».

Table 2 - Knowledge base of the expert system

№	X_1	X_2	Y_1	Y_2	Y_3
1	AX1	AX2	CY1	CY2	CY3
2	BX1	AX2	AY1	CY2	CY3
3	CX1	AX2	CY1	AY2	AY3
4	BX1	CX2	CY1	CY2	CY3
5	CX1	AX2	CY1	AY2	AY3

In fig. 3 shows the surface of the fuzzy conclusion. The analysis of surfaces allows to draw the following conclusions:

- standard infestation of grain (85,6-85,7) % will be with air temperature 25 °C and relative humidity air (83-84) %;
- high infestation of the grain (87,9-88,5) % will be with air temperature (22-28) °C and relative humidity air (87-88) %;
- long duration of *Sitotroga cerealella Oliv.* (34,3-34,7) days will be with air temperature (22-25,5) °C and relative humidity air 83 %;

- short duration of *Sitotroga cerealella Oliv.* 29,4 days will be with air temperature 28 °C and relative humidity air 83 %;
- standard weight eggs of *Sitotroga cerealella Oliv.* (9,09-9,67) g / kg of barley grain will be with air temperature (22-26) °C and relative humidity air 83 %;
- low weight eggs of *Sitotroga cerealella Oliv.* (7,4-7,91) g / kg of barley grain will be with air temperature (27-28) °C and relative humidity air 83 %.

The average error of approximation between the experimental data and the fuzzy conclusion is Y1 - 1.39%, Y2 - 6.71%, Y3 - 6.86% (does not exceed 8-10%) [11].

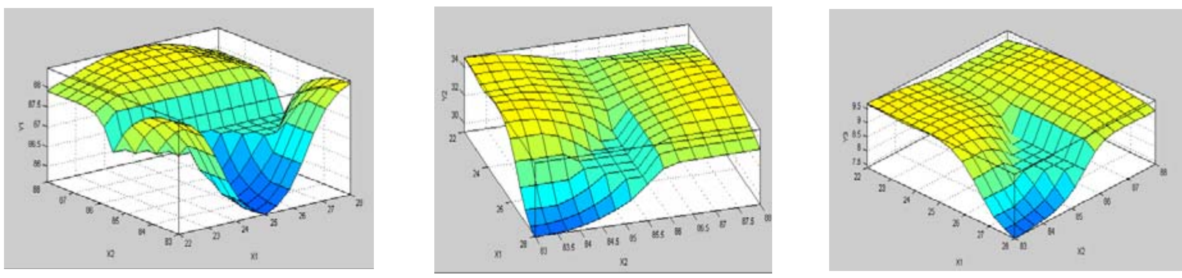


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Fig. 3 Surface of the fuzzy conclusion: a) dependence infestation of grain of Sitotroga cerealella Oliv. from air temperature and relative humidity; б) dependence duration of development of Sitotroga cerealella Oliv. from air temperature and relative humidity; в) dependence weight eggs of Sitotroga cerealella Oliv. from air temperature and relative humidity

To improve the accuracy of the fuzzy model, the model is taught, that is, its parameters are changed iteratively to minimize the deviation of the results of the logical sampling from the experimental data [12].

Conclusions

Structural and intellectual methods of designing bioengineering complexes for insect culture production, which can be useful for the subsystem of decision making when creating control systems for the production of entomophages according to the quality criterion, are developed. The application of the theory of fuzzy sets makes it possible to trace the influence of parameters on the quality indicators of culture insects in conditions of a limited number of input data, save time to work out the necessary solutions.

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