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OPTIMIZATION OF ARTIFICIAL NUTRIENT FOR GROWING *COCCINELLIDAE*

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Abstract. The technological parameters for the optimization of a diet for breeding predatory *Coccinellidae* are offered. An optimized diet contains: soy flour, sucrose, milk powder, palm kernel oil, Wesson salt, dry beer yeast, tocopherol, vitamin C, agar-agar, vitamin B_1, vitamin B_6, vitamin B_{12}, metaben, inositol, egg yolks, cryopreserved eggs, larvae and imago of insect phytophages in the ratio 1: 1, and nano aqua citrate microelements. The components included in the diet at optimal concentrations act as biologically and physiologically active nutrients. The proposed nutrient diet at a reasonably high level ensures reproductive potential growth, the emergence of the imago, improving search capacity and increasing the appetite of *Coccinellidae* in the post-embryonal period. As a result of modification of qualitative and quantitative indices of the nutrient diet, there are positive changes in the biology of predatory *Coccinellidae*, which improve their competitive ability in biocenoses.

Key words: *Coccinellidae*; Nutrient diet; Survival; Reproductive potential; Search capacity.

INTRODUCTION

The world practice argues that the intensive development of new pesticides and the improvement of their use technology does not solve environmental problems. An alternative to insecticides is the involvement of effective entomophages in agrocenosis. As biological agents for limiting harmful phytophages, predatory *Coccinellidae* are used in the countries of Europe and America. Of the 6000 species of coccinellids worldwide described, they are mostly insatiable predators of many phytophages and require animal food such as aphids, coccidia, and ticks (Almeida, L.M. et al. 2011; Ahmed, K.S. et al. 2017). In the process of evolution, *Coccinellidae* was used in a variety of nutrition strategies under conditions of food shortages (Sloggett, J.J., Majerus, M.E. 2000). In the absence of the main food, they feed on pollen of flowers, nectar and juice of plants (Almeida, L.M. et al. 2011).

The ability of predatory *Coccinellidae* to be used as additional food for other insects, as well as to partially switch to plant food, helps them to accumulate energy resources to maintain their existence in changing environmental conditions. The degree of satisfaction of the nutritional requirements of the organism at all stages of ontogenesis depends on the viability, fertility and biological efficacy of beneficial insects (Hesler, L.S. et al. 2012; Moroz, M.S. 2015; Moroz, N.S. 2015; Moroz, M.S. 2016).

In Ukraine, autochthonous species of *Coccinellidae* for their biological diversity and ecological peculiarities are a unique natural source for the creation of entomological technologies and for practical application in the biological protection of plants. The studies on adaptation and further optimization of trophism contribute to a better understanding of the ethology of *Coccinellidae* in the new environment, which is essential for the advancement of the theory and practice of biological control (Alyokhin, A., Sewell, G. 2004; Hesler, L.S. et al. 2012). Research aim – to study the effectiveness of an optimized artificial nutrient diet for the breeding of predatory *Coccinellidae*.

To achieve this goal, the following tasks were addressed:

– to create an optimized artificial nutritional diet for breeding carnivorous *Coccinellidae*;

– to study the peculiarities of the biology of predatory *Coccinellidae* for the use of optimized artificial nutritional diet;

– to evaluate the potential opportunities of predatory *Coccinellidae* grown on optimized artificial nutritional diet as biological agents for limiting the harmfulness of aboriginal phytophages.

MATERIALS AND METHODS

The research was carried out in accordance with the biological characteristics of predatory species from the *Coccinellidae* family on the experimental basis of the National University of Life and Environmental Sciences of Ukraine. The efficiency of an optimized nutritional diet was studied for seven generations on laboratory cultures of *Cryptolaemus montrouzieri* Muls., *Cycloneda limbifer* Casey., *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L., *Adonia ver-*

iegata Gz. The optimized nutrient diet for the cultivation of predatory *Coccinellidae* was prepared as follows. In accordance with the extreme and mean values of the components of the experimental variants presented in Table. 1, weighed components of soy flour, sucrose, milk powder, palm kernel oil, Wesson salt, dry beer yeast, tocopherol, vitamin C, agar-agar, vitamin B_1, vitamin B_6, vitamin B_{12}, metaben, inositol, egg yolk, cryopreserved eggs, larvae and imago of insect phytophages in the ratio of 1: 1, and the nano aqua citrate microelements were premixed before obtaining a homogeneous mass. Breeding of predatory *Coccinellidae* (*Cryptolaemus montrouzieri* Muls., *Cycloneda limbifer* Casey., *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L., *Adonia veriegata* Gz.) was carried out at a temperature of 24 ± 1 ^{0}C, relative humidity of 80 ± 5% and photoperiod – 16 hours. Larvae and Imago of the control variants of laboratory cultures of predatory *Cryptolaemus montrouzieri* Muls., *Cycloneda limbifer* Casey., *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L., *Adonia veriegata* Gz. were grown on a known nutrient diet (Patent RU 2520860 C2).

Table 1. *Content of components in the nutrient diet of experimental variants used for the cultivation of predatory Coccinellidae*

Component name	Concentration, mass %				
	Options				
	A	B	C	D	E
soy flour	9,1	9,2	9,35	9,4	9,5
saccharose	9,2	9,4	9,55	9,6	9,7
dry milk	1,7	1,8	1,9	1,95	1,96
palm kernel oil	2,1	2,2	2,25	2,3	2,35
Wesson's salt	1,25	1,3	1,31	1,32	1,322
dry beer yeast	2,15	2,2	2,25	2,3	2,31
tocopherol	0,017	0,02	0,022	0,025	0,0251
vitamin C	0,09	0,1	0,11	0,12	0,121
agar-agar	2,045	2,05	2,06	2,08	2,085
vitamin B_1	0,0047	0,005	0,0055	0,0058	0,0059
vitamin B_6	0,0047	0,005	0,0055	0,0058	0,0059
vitamin B_{12}	0,00008	0,0001	0,00011	0,00012	0,00014
metaben	0,06	0,1	0,105	0,106	0,107
inositol	0,0008	0,001	0,0012	0,0013	0,0014
chicken egg yolk	1,7	1,8	1,85	1,9	1,95
Cryopreserved eggs, larvae and imago of insect phytophages in the ratio of 1: 1	4,3	4,5	4,6	4,8	5
nano aqua citrate microelements	0,00128	0,00184	0,0021	0,002322	0,002433
distilled water	66,27644	65,31706	64,62859	64,08366	63,55413

RESULTS AND DISCUSSIONS

The results of experiments on the influence of the nutrient diet on the ontogenesis of the zoophages from the *Coccinellidae* family are presented in Table 2. The analysis confirms that the best indicators for the survival of the first and second generation of zoophages from the *Coccinellidae* family are obtained in experimental variant C.

In this variant, the survival of the first and second generation of predatory *Coccinellidae* was on average for *Cryptolaemus montrouzieri* Muls. – 77% and 74%, *Cycloneda limbifer* Casey. – 80% and 76%, *Coccinella septempunctata* L. – 84% and 81%, *Coccinella bipunctata* L. – 82% and 78%, *Hyppodamia tredecimpunctata* L. – 81% and 76%, and *Adonia veriegata* Gz. – 79% and 75%, respectively 16 and 19%, 17 and 25%, 18 and 32%, 15 and 28%, 19 and 28%, and 14 and 25% respectively, compared with the control variant. The proposed component composition of the nutrient diet of the experimental variants not only provides high survival rates in two generations of predatory *Coccinellidae* (*Cryptolaemus montrouzieri* Muls., *Cycloneda limbifer* Casey., *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L. and *Adonia veriegata* Gz.), but also positively affects the increase in their reproductive capacity in the second and third generations.

Table 2. *Influence of nutrient diet on ontogeny of predatory Coccinellidae*

Indexes	Options					
	A	B	C	D	E	Control
Survival F_1, %:						
Cryptolaemus montrouzieri	73	76	77	75	72	61
Cycloneda limbifer	74	78	80	79	74	63
Coccinella septempunctata	76	81	84	83	77	66
Coccinella bipunctata	72	79	82	80	76	67
Hyppodamia tredecimpunctata	71	77	81	78	73	62
Adonia veriegata	73	78	79	77	73	65
Survival F_2, %:						
Cryptolaemus montrouzieri	68	71	74	73	69	55
Cycloneda limbifer	66	72	76	75	61	51
Coccinella septempunctata	69	78	81	77	68	49
Coccinella bipunctata	67	75	78	75	69	50
Hyppodamia tredecimpunctata	64	69	76	73	67	48
Adonia veriegata	63	74	75	73	68	50
Reproductive potential(R_p) n=2, specimen:						
Cryptolaemus montrouzieri	945	973	1001	995	884	790
Cycloneda limbifer	953	1091	1125	1102	956	843
Coccinella septempunctata	703	721	744	740	705	651
Coccinella bipunctata	699	745	801	789	733	629
Hyppodamia tredecimpunctata	974	980	1002	997	972	815
Adonia veriegata	708	775	800	782	770	607
Reproductive potential(R_p) n=3, specimen:						
Cryptolaemus montrouzieri	1406	1468	1501	1473	1410	1320
Cycloneda limbifer	1504	1592	1687	1601	1534	1388
Coccinella septempunctata	921	954	1073	968	931	892
Coccinella bipunctata	905	971	1092	983	911	875
Hyppodamia tredecimpunctata	1408	1502	1553	1536	1494	979
Adonia veriegata	1001	1053	1110	1062	1007	885

According to the results obtained, the additionally introduced components of the experimental variants of the nutrient diet significantly increased the rate of reproduction of predatory *Coccinellidae*: *Cryptolaemus montrouzieri* Muls., *Cycloneda limbifer* Casey., *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L. and *Adonia veriegata* Gz. Thus, as a result of breeding of predatory *Coccinellidae* in two generations, the reproductive potential of one female in experimental variants B, C and D was on average for *Cryptolaemus montrouzieri* Muls. – 973, 1001 and 995 specimens, *Cycloneda limbifer* Casey. – 1091, 1125 and 1102 specimens, *Coccinella septempunctata* L. – 721, 744 and 740 specimens, *Coccinella bipunctata* L. – 745, 801 and 789 specimens, *Hyppodamia tredecimpunctata* L. – 980, 1002 and 997 specimens and *Adonia veriegata* Gz. – 775, 800 and 782 specimens, which is respectively 23.16, 26.71 and 25.95%; 29.42, 33.45 and 30.72%; 10.75, 14.29 and 13.67%; 18.44, 27.34 and 25.44%; 20.25, 22.94 and 22.33%, and 27.68, 31.80 and 28.83%, relatively more than the control version.

The estimated average reproductive potential of predatory *Coccinellidae* in the three generations of experimental variants B, C and D was also the highest. For example, for the most optimal experimental variant C, the reproductive potential of three generations of one female was on average for *Cryptolaemus montrouzieri* Muls. – 1501 specimens, *Cycloneda limbifer* Casey. – 1687 specimens, *Coccinella* *septempunctata* L. – 1073 specimens, *Coccinella bipunctata* L. – 1092 specimens, *Hyppodamia tredecimpunctata* L. – 1553 specimens and *Adonia veriegata* Gz. – 1110 specimens, correspondingly more than 13.71%, 21.54%, 20.29%, 124.8%, 58.63% and 25.42% compared to the control version.

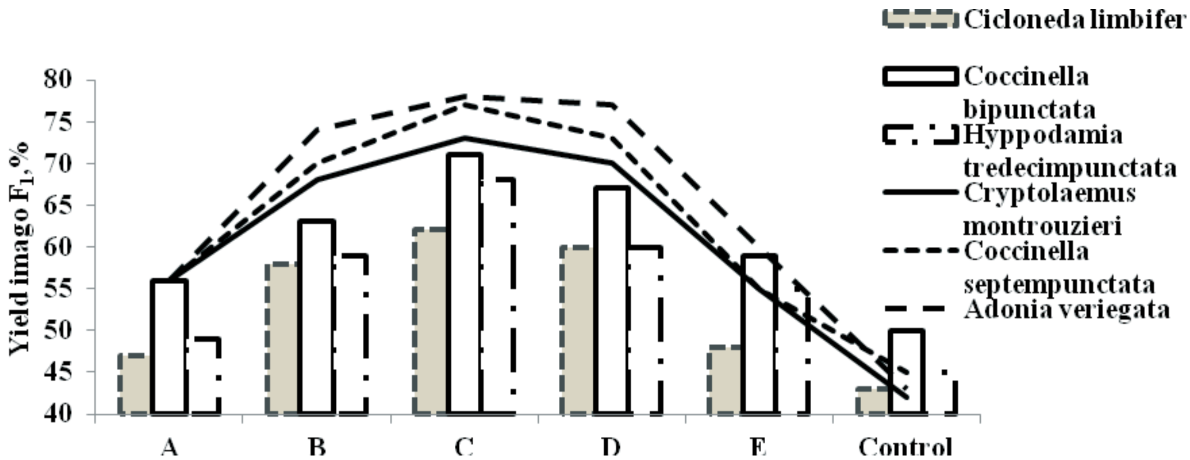

Figure 1. *Influence of the nutrient diet on the output of the first generation imago of predatory* Coccinellidae *(2011-2017 years, average values)*

Thus, it is experimentally grounded that additional components in the optimum concentrations introduced into the nutritional diet act as nutrient biological and physiologically active ingredients, and in the process of ontogenesis of three generations provide the optimal development of the population of predatory *Coccinellidae*. When *Cryptolaemus montrouzieri* Muls., *Cycloneda limbifer* Casey., *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L. and *Adonia veriegata* Gz. are grown on the proposed nutrient diet, in the process of ontogenesis, at a high level of survival, the reproductive potential of entomophages in three generations is ensured.

It should be noted that the increase in the quantitative values of the constituents of the nutrient diet and the reduction of water in it, as shown in variant E, does not substantially increase the survival of the first and second generation of predatory *Coccinellidae Cryptolaemus montrouzieri* Muls., *Cycloneda limbifer* Casey., *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L. and *Adonia veriegata* Gz., and also does not contribute to the growth of reproductive potential of females, therefore it is economically not feasible. The influence of the nutrient diet on the yield of the first-generation imago of predatory *Coccinellidae* is shown in Fig. 1. From the data presented in Fig. 1 it is evident that using the proposed nutrient diet for the cultivation of the zoophagous *Cryptolaemus montrouzieri* Muls., *Cycloneda limbifer* Casey., *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L. and *Adonia veriegata* Gz. the yield of the first-generation imago is significantly increased. Thus, in the experimental variants B, C, and D the first-generation imago was on average in the population of *Cryptolaemus montrouzieri* Muls. – 68, 73 and 70%, *Cycloneda limbifer* Casey. – 58, 62 and 60%, *Coccinella septempunctata* L. – 70, 77 and 73%, *Coccinella bipunctata* L. – 63, 71 and 67%, *Hyppodamia tredecimpunctata* L. – 59, 68 and 60%, and *Adonia veriegata* Gz. – 74, 78 and 77%, respectively 26, 31 and 28%, 15, 19 and 17%, 25, 32 and 28%, 13, 21 and 17%, 14, 23 and 15% and 31, 35 and 34% more compared to the control variant.

Figure 2 shows the effects of the nutrient diet on the yield of imago of the predatory *Coccinellidae* of the second generation. According to the obtained results, the additionally introduced components of the nutrient diet of the experimental variants significantly increased the yield of imago of *Cryptolaemus montrouzieri* Muls., *Cycloneda limbifer* Casey., *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L. and *Adonia veriegata* Gz. of the second generation. Thus, in the most optimal experimental variant C, the yield of imago of predatory *Coccinellidae* of the second generation was on average in the population of *Cryptolaemus montrouzieri* Muls. – 66%, *Cycloneda limbifer* Casey. – 57%, *Coccinella septempunctata* L. – 69%, *Coccinella bipunctata* L. – 59%, *Hyppodamia tredecimpunctata* L. – 59%, and *Adonia veriegata* Gz. – 73%, which is 26%, 18%, 31%, 15%, 23% and 37%, respectively, more compared to the control.

The results of studies on the influence of the nutrient diet on the search capacity and insatiability of the second-generation larvae of *Cryptolaemus montrouzieri* Muls. as regards eggs of *Planococcus citri* R. are presented in Fig. 3. The analysis shows that the best indicators of search ability, gluttony, and destruction of *Planococcus citri R.* eggs by the second generation larvae of *Cryptolaemus montrouzieri* Muls. were observed in experimental variants. If the average indicator of destroyed eggs of *Planococcus citri R.* by larvae of the control variant is taken as one hundred percent, the percentage of killed eggs of *Planococcus citri R* in the experimental variants has a significantly higher difference and reaches 150%.

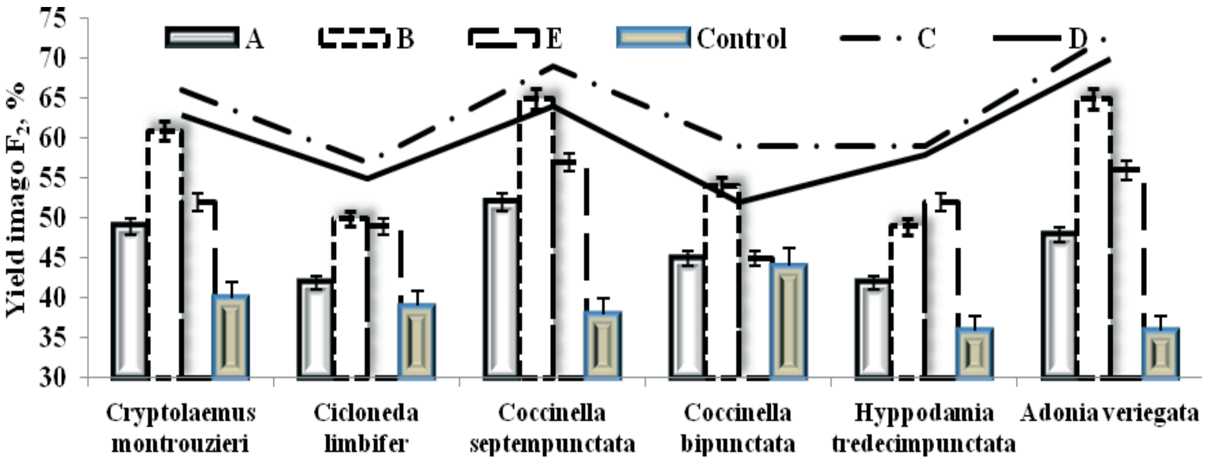

Figure 2. *Influence of the nutrient diet on the yield of imago of the predatory Coccinellidae of the second generation (2011-2017 years, average values)*

Visual surveys showed that immediately following hatching the second generation larvae of *Cryptolaemus montrouzieri* Muls. of the experimental variant began to eat the eggs of the phytophagous host. As they evolved, they became more mobile and predatory towards larvae and the imago of *Planococcus citri* R. – a dangerous harmful phytophagus of grapes, citrus and greenhouse subtropical plants.

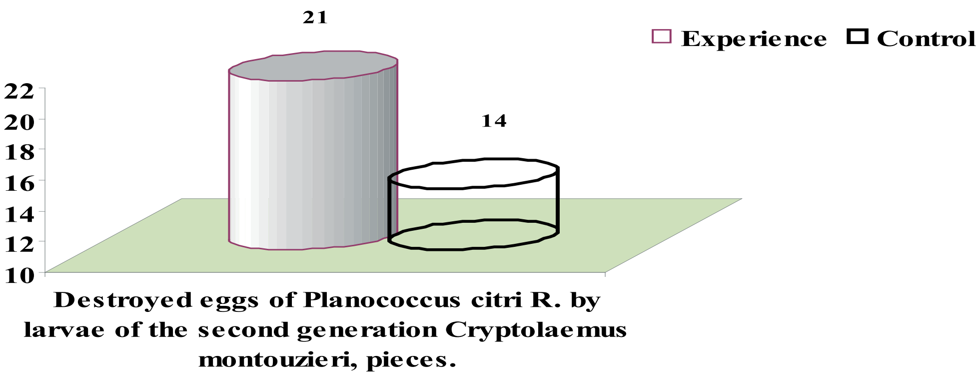

Figure 3. *Influence of the nutrient diet on the search capacity and covetousness of the second generation larvae of Cryptolaemus montrouzieri Muls. as regards eggs of Planococcus citri R . (2013-2017 years, average values)*

The results of experiments on the influence of the nutrient diet on the search capacity and voracity of the second generation *Cycloneda limbifer* Casey. with respect to *Aphis gossypii* Glov. are shown in Figure 4. According to the results the predatory *Cycloneda limbifer* Casey. in experimental variants is characterized by high indexes of search ability of larvae and imago of the phytophagous aphid *Aphis gossypi* Glov. with their subsequent eating. Thus, the *Cycloneda limbifer* Casey. (experience) found and destroyed 185 of *Aphis gossypi* Glov., which is 88.78 percent more than the control variant.

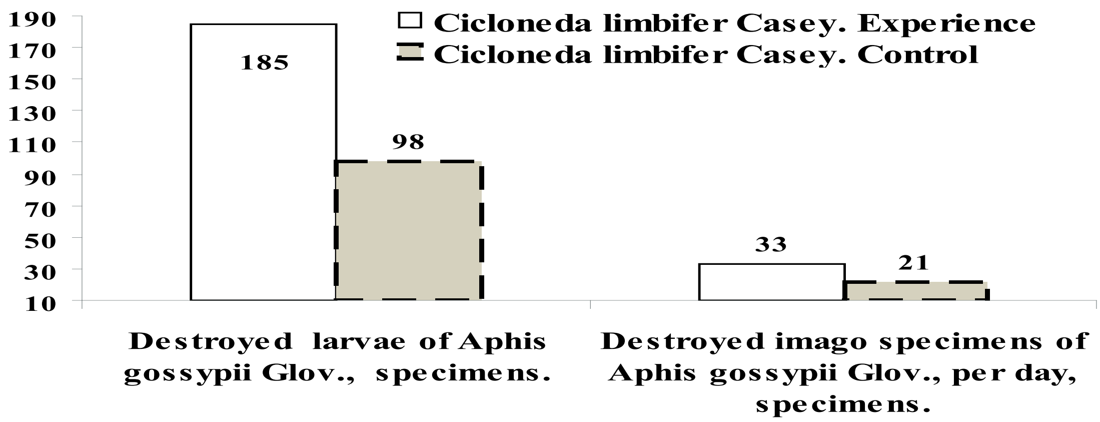

Figure 4. *The influence of the nutrient diet on the search capability and voracity of the second generation of Cycloneda limbifer Casey. on the larvae and imago of Aphis gossypii Glov. (2011-2017 years, average values)*

Undoubtedly, the second generation of Cycloneda limbifer Casey. of experimental variants showed efficiency for the search and destruction of the *Aphis gossypi* Glov. insect host imago. So, one specimen of the second generation of carnivorous *Cycloneda limbifer* Casey. in experimental variants found and destroyed 33 specimens of *Aphis gossypi* Glov. for a day, which is 57,14% more compared to the control variant.

In fig. 5 the results of the influence of the nutrient diet on the search capacity and voracity of the second-generation *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L. and *Adonia veriegata* Gz. are presented as regards *Schizaphis graminum* Rond. From the presented indicators in Figure 5 it is obvious, that using the proposed nutrient diet for the cultivation of *Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L. and *Adonia veriegata* Gz., the search capacity and insatiability of the second generation of predatory *Coccinellidae* remains at a high level. Thus, the second-generation experimental carnivorous *Coccinellidae* found and destroyed the following number *of Schizaphis graminum* Rond. individuals, on average per day: *Coccinella septempunctata* L. – 66 specimens, *Coccinella bipunctata* L. – 85 specimens, *Hyppodamia tredecimpunctata* L. – 74 specimens and *Adonia veriegata* Gz. – 90 specimens, which is respectively 37.5%, 39.34%, 39.62% and 40.63% more than the control version. A comprehensive analysis of experimental data shown in the form of a digital material and presented in Tables 1 and 2, Figures 1-5 shows that for all studied properties, the modified nutrient diet with functional biological and physiologically active ingredients have an advantage over the parameters of the control variant. The technical solution of the nutritrient diet for the cultivation of zoophages is that the optimization of postembryonic development, survival, increased reproductive potential, yield of imago, improvement of search capacity and gluttony of *Coccinellidae* during postembryonic development is observed.

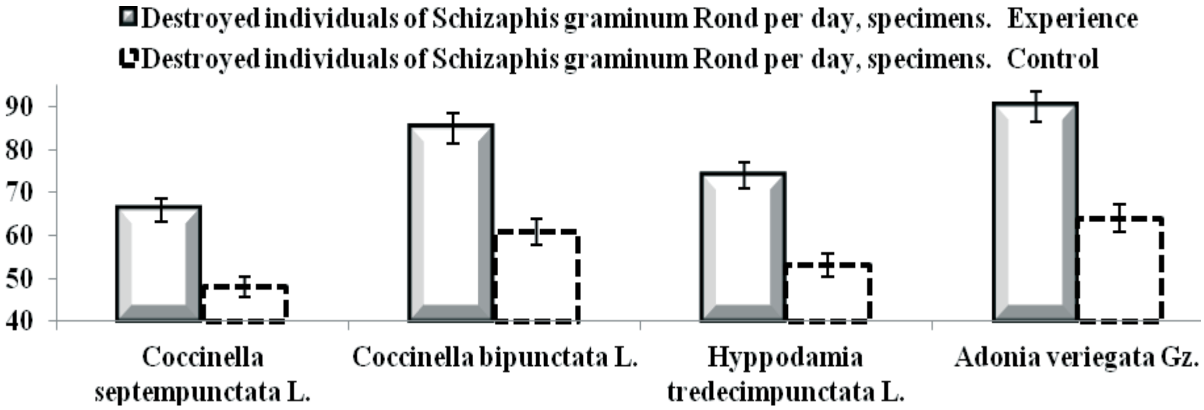

Figure 5. *Influence of the nutrient diet on the search capacity and voracity of the second generation of Coccinella septempunctata* L., *Coccinella bipunctata* L., *Hyppodamia tredecimpunctata* L. and *Adonia veriegata* Gz. relative to *Schizaphis graminum* Rond., *(2013-2017 years, average values)*

Scientific researches aimed at developing practical bases for breeding, improving the formula for nutrition, and also methods for optimizing the structure of laboratory populations and industrial cultures of *Coccinellidae* have been formed. Such an approach to the problem, in our opinion, is consistent with the strategy for the conservation of biological diversity of ecosystems. It corresponds to one of the main areas of research of countries that are members of the Pan European Ecological Network for preserving, restoring and improving natural and disturbed ecosystems (Moroz, M.S., Maksin, V.I. 2015; Moroz, M.S., Starodub, M.F., Maksin, V.I. 2015).

CONCLUSIONS

1. The optimization of *Coccinellidae* development is observed with the use of the optimized nutritional diet.
2. The proposed nutrient diet provides for the growth of reproductive potential, the release of the imago, improving search capacity and increasing the hunger of predatory *Coccinellidae* in the post-embryonic period.
3. As a result of modification of qualitative and quantitative indices of the nutrient diet there are positive changes in the biology of predatory *Coccinellidae*, which improves their competitive ability in biocenoses.

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