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Phene Structure of the Population of 14 Spot Ladybird *Propylea quatuordecimpunctata* (Linnaeus, 1758) in the Republic of Tatarstan (Russia)

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Abstract

The work is devoted to studying the phene structure of populations of 14-spot ladybird (Propylea quatuordecimpunctata (Linnaeus, 1758)), localized in Elabuga and Muslyumovsky areas of the Republic of Tatarstan. The variability of isolated beetle phene is shown—seven yellow spots on the elytra black background. Positive asymmetry of the phene aberration shows the reduced size of these spots, compared with the average one, i.e., increased melanization of elytra. Between all the signs conjugate variability manifested, which indicates that they linked inheritance in the genotype.

Keywords

Propylea quatuordecimpunctata (Linnaeus, 1758); Polymorphism; Phene variability; Phene; Aberration; Asymmetry; Conjugate variability

Introduction

Polymorphism is one of the toughest general biological phenomena that requires a continuously new interpretation of its significance. Currently, the greatest value in the evaluation system is the question about the reasons leading to the variability of characteristics and properties of organisms, the role of gene pools in the implementation of this important property of living matter.

One of the prospective methods of detecting population structure is the phene approach. Convenient objects for studying phene polymorphism are insects. The most suitable for this purpose are the following characteristics: the degree of the melanism of the cover, [1] ratio between the compared patterns of shapes signs of dark overwintered and the light-color insects [2], the character and the degree of asymmetry features [3]. Polymorphism of beetles' patterns covers is determined by genetic and environmental factors [4], which suggest the possibility of using the nature of this type of polymorphism for bioindication.

Polymorphism has essential adaptive value. The presence in the population of the various shapes and all kinds of transitions between them make the population highly ductile. The level of cover melanization shows how living conditions affect on the signs of the bugs, both on the genetic level, and the external manifestation. The increase in the population of the rare "mutant" forms indicates the extremality of their habitat and the existence of microevolutionary processes.

The study of the phene variability of the insect is devoted to a lot of work of domestic and foreign researchers: Ya.Ya. Lucys [5]; I.V. Batlutskaya [6]; O.V. Korsun [7]; S.M. Molodtsov [8]; E.P. Klimets [9]; E.Yu. Zakharova [10]; T.S. Korol, T.G. Novoselskaya [11]; R.M. Zeleev [12]; O.A. Sherstneva [13]; I.N. Isayeva [14]; Yu.G. Kholodova [15]; G.K. Turabaevoy *et al.* [16]; K. Porter [17]; M.F. Braby [18]; D.F. Owen, D. Goulson [19]; S. Van Dogen [20]; R.O. Butovsky, K.B. Gongalsky [21]; S. Hardersen *et al.* [22]; Z. Fric, M. Konvicka [23]; B. Seifert [24]; B. Seifert, A.V. Goropashnaya [25]; J. Sorvari [26].

In our work, the model object of the polymorphism study is a 14-spot ladybird (Propylea quatuordecimpunctata (Linnaeus, 1758)). The aim of the study was to exam the polymorph structure of populations of the species in Elabuga and Muslyumovsky areas of the Republic of Tatarstan (the RT)—subject of the Russian Federation.

There are two forms of beetle covers coloring: yellow with black pattern and black with yellow pattern. In summer, there are the second forms. Pattern on ladybirds' elytra can vary considerably with the whole gamut of gradual transitions. Body length is up to 5 mm. Sexual dimorphism is weak. In most species, the top of the fifth or sixth sternite in males is with a notch or pit, in females—with knobs. Sometimes males and females differ in pattern on the pronotum [27]. Aphidophagous. Hortodendrobiont. Hydromesophils (lives in grass and trees with high humidity). Imago spends the winter. Imago and juvenile phase are predators, exterminating aphids' psyllites, scale insects, mealy bugs and mites bring enormous benefit to agriculture.

Method

The field material was collected near the v. Narat-Asta (Muslyumovsky district RT) and near the town of Elabuga (Elabuzhsky district RT) in June-July 2011-2012. We studied populations at two sites, separated from each other by 85 km. From each plot we collected 80 specimens of adults. The sites did not differ in the main physical and climatic characteristics. In our work, we have studied only pattern elytra of each individual (aberration spots) with the help of a stereoscope MSP-1 (option 2). The measurement of metric parameters was carried out using an eyepiece micrometer at 4× magnification.

Pattern of the beetle elytra was formed by seven yellow spots around shape, arranged in two rows on black elytra. These individual spots were taken by us for phenes and were indicated in the order of the sequence of A, B, C, D, E, F, G (Figure 1).

The methodological basis of the work was to conduct a comparative analysis of the phene aberrations, their coefficients of asymmetry (As), and correlative variability in both elytra of beetles in the studied populations. For comparative analysis of the morphometric parameters, we used the algorithm calculations by the method of G.F. Lakin [28].

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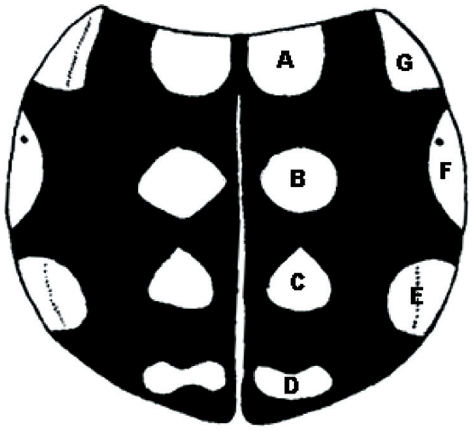

Figure 1: The signs of the design of melanized formed elytra of 14-spot ladybird *Propylea quatuordecimpunctata* (Linnaeus, 1758) (origin)

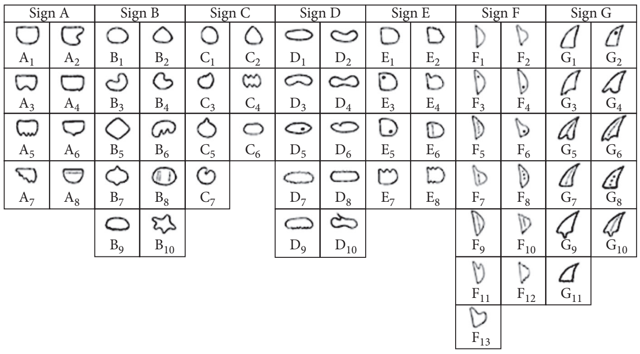

Figure 2: The catalog of signs of elytra of *Propylea quatuordecimpunctata* (Linnaeus, 1758) in populations, localized in the Elabuga and Muslyumovo districts of the Republic of Tatarstan (Russia) (origin)

Results and Discussion

To study the structure of polymorph structure of the studied characters, it was important to compile a directory of the pattern elytra phenes of this type to identify the spectrum of variability—aberrations. Each phene was characterized by a variety of aberrations in the two examined populations, a set of data is given in the form of directory (Figure 2). Of course, the union of the set of forms of yellow spots in certain aberration is conditional, but it allows to reduce their number and to simplify the analysis. A phene was presented in the 8 aberrations, phene B—10, phene C—7, phene D—10, phene E—8, phene F—13 and phene G—11 aberrations. Their description was made with the aim of compiling a catalog of fen elytra. During a detailed study these spots often have an irregular shape with a constriction, spikes, with dark spots inside and with serrated edges. In all this variety of aberrations there is an allocated unbalanced distribution of yellow spots on both elytra of beetles, in what a uniqueness of the pattern in each individual appears.

Aberrations of allocated phenes in both populations had different incidence in the left and right of beetles elytra. Here, because of the large amount of information, we cannot show all the data on the frequency distribution of the aberrations of each phene, and give only a summary. With the highest frequency in the "Elabuga" population prevailed beetles with aberrations on, respectively, left and right elytra: A_2-A_8, B_1-B_1, C_1-C_6, D_1-D_2, E_6-E_4, F_1-F_1, G_9-G_3(G_{10}); in "muslyum" is similar to: A_8-A_1, B_3-B_1, C_1-C_2, D_2-D_1, E_6-E_1, F_{12}-F_{12}, G_1-G_4.

The lowest frequency of aberrations in the I population had: A_6 (A_7)-A_4, B_4 (B_7)-B_6(B_8), C_5-C_4, D_7-D_3, E_8-E_2, F_6(F_8)-F_{12}(F_{13};F_8), G_2-G_2(G_7) on the left and right elytra, respectively; in the II population, similar to: A_3-A_8, B_{10}- B_4(B_5), C_4-C_1(C_3;C_4), D_9-D_{10}, E_8-E_5, F_8(F_9)-F_4, G_2(G_7;G_8)-G_2(G_{11}).

In the most occurrences of certain aberrations of different phenes we drew up "typical" phene image of 14-spot ladybird elytra for both populations, which are shown in Figure 3. We can see asymmetrical arrangement of spots on the left and right elytra in each of the beetles' populations.

In addition, both populations have rare singularly beetles with unique individual aberration fen: A_6; A_7; B_6; B_8; B_{10}; D_{10}; F_9+G_7; F_8+G_2; G_8+A_1 (Figure 4). Among the beetles there were no completely black forms without any spots. There were no yellow color variations.

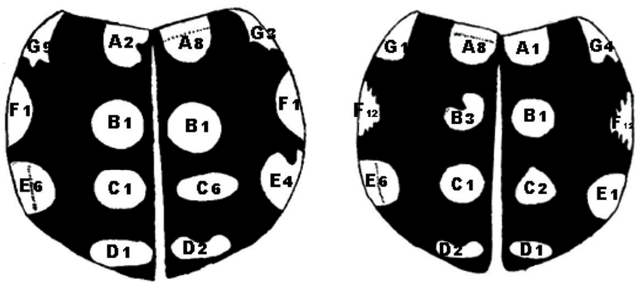

Figure 3: The "typical" phenotypes of the design of elytra of *Propylea quatuordecimpunctata* (Linnaeus, 1758): left—population, localized in the Elabuga district; right—population, localized in the Muslyumovo district (origin)

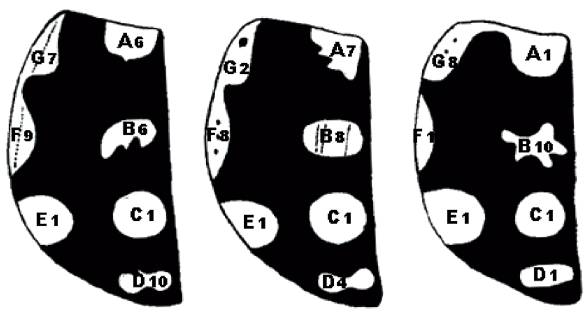

Figure 4: The rare phenotypes of the design of elytra with nontypical aberration of signs of *Propylea quatuordecimpunctata* (Linnaeus, 1758) in populations of Elabuga and Muslyumovo (origin)

A number of authors [29] observed melanization of the covers as an adaptive significance of insects. Insects with black color breed so intensively in the summer and have a high frequency of occurrence. The forms with red, yellow covers are more tolerate to the low temperatures in the winter.

During the summer, black melanized 14-spot Ladybird was dominated. By the degree of development of yellow spots on the elytra in different populations can be judged on their subtle differences, and by the presence of different mutations (jumpers and additional

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elements between the spots)—about the extent of favoring their habitat. Normally, in any population which is in optimal conditions, average phenotypes are predominating with increased frequency. During the evolution form of selection to one or another form, forms that deviate from the average phenoimage appear in the population [30].

At the 14-point Ladybugs this can manifest itself in an increase or decrease in the size of yellow spots on the elytra, the presence of atypical spots that may indicate some processes that affect on specific populations in specific circumstances. These shifts allow to detect the asymmetry coefficient. When the positive asymmetry average value characteristic is shifted in the direction of its decrease, when negative, on the contrary, increased.

Comparison of the elytra phene asymmetry coefficients in two populations revealed the existence of some differences, which makes them unique. In this case, all the phenes that forming elytra pattern in both considered populations had a statistically significant decrease ($\alpha = 1\%$) in the size of yellow spots on the black background, compared with the average type of the theoretical distribution (Table 1). This indicates about somewhat elevated degree of elytra melanization, i.e., the predominance of the black color. As it was noted above, insects with black color covers are more intensive in breeding.

In the both studied populations equal reduction of the size of the spots of the phenes A, B, D, G was observed. The maximum reduction in spots of phenes C, E was typical in the population of Elabuga district, spots of the phene F—in Muslyumovsky area.

Kurtosis coefficients reflect the degree of concentration of the central characters in a series of variations grades: +Ex shows the maximum concentration, −Ex—“spray” of the characteristic values. Negative kurtosis was detected only in two cases: for the phene C—in “Muslyumovsky” population and for the phene G—in the “Elabuga” population.

In order to identify correlations between these phenes, we carried out a comparative analysis of the conjugate variability of the elements of the left elytra pattern. This method allows to indirectly identifying the existing relationship between the variability of signs, if they exist. The presence of such interdependence between signs variability indicates the existence of symptoms linked into the genotype.

Phene	$\bar{X} \pm S_{\bar{x}}$	α, %	As	α, %	Ex	α, %
A	1.56 ± 0.05	–	1.68	1	0.14	–
	1.53 ± 0.04		1.76	1	0.53	–
B	1.17 ± 0.02	–	1.69	1	0.56	–
	1.18 ± 0.01		1.96	1	1.25	1
C	1.07 ± 0.03	–	2.36	1	5.00	1
	1.06 ± 0.02		1.37	1	−0.98	1
D	1.89 ± 0.07	–	2.02	1	1.75	1
	1.78 ± 0.06		1.96	1	1.70	1
E	0.08 ± 0.02	–	2.34	1	4.7	1
	0.87 ± 0.02		1.78	1	0.89	1
F	0.79 ± 0.02	–	1.62	1	0.03	–
	0.76 ± 0.03		2.68	1	5.45	1
G	1.27 ± 0.03	–	1.50	1	−0.44	–
	1.20 ± 0.03		1.79	1	0.75	–

Note: above the line—the population in the Elabuga district; below the line—the population in the territory of the Muslyumovsky area.

Table 1: Values of the asymmetry and kurtosis coefficients of the left elytra phene in the study population Propylea quatuordecimpunctata (Linnaeus, 1758)

Phenes	A	B	C	D	E	F	G
A	–	0.71	0.58	0.64	0.62	0.69	0.65
B	–	–	0.58	0.81	0.58	0.77	0.64
C	–	–	–	0.60	0.43	0.65	0.64
D	–	–	–	–	0.52	0.77	0.62
E	–	–	–	–	–	0.55	0.65
F	–	–	–	–	–	–	0.68
G	–	–	–	–	–	–	–

Table 2: The values of the correlation coefficients (r_{xy}) of the left elytra phene in the populations Propylea quatuordecimpunctata (Linnaeus, 1758), localized in Elabuga

Phene	A	B	C	D	E	F	G
A	–	0.59	0.65	0.69	0.67	0.72	0.51
B	–	–	0.58	0.65	0.59	0.66	0.60
C	–	–	–	0.70	0.65	0.60	0.71
D	–	–	–	–	0.62	0.75	0.47
E	–	–	–	–	–	0.70	0.61
F	–	–	–	–	–	–	0.50
G	–	–	–	–	–	–	–

Table 3: The values of the correlation coefficients (r_{xy}) of the left elytra phene in the populations Propylea quatuordecimpunctata (Linnaeus, 1758), localized in Muslyumovsky area

In the article we considered the correlative relationship between left elytra phenes (Tables 2 and 3), as it is sufficient to find the conjugate variation on the one of the elytra. It was found that among all the phenes there is a conjugate variability from the average to the maximum.

The average values of the correlation coefficient in the population localized in Elabuga were obtained for the following pairwise comparisons: A-C—0.58; B-C—0.58; B-E—0.58; C-D—0.60; C-E—0.43; D-E—0.52; E-F—0.55. Maximum conjugate was found between phenes: A-B—0.71; A-F—0.69; B-D—0.81; B-F—0.77; D-F—0.77. In the rest of the phenes there was a significant correlation, above average. In all cases positive correlative relationship between the phenes was detected that confirms the assumption about the conjugate variability of the characters (Table 2).

In a population localized in Muslyumovsky area average correlations were typical for the following features (Table 3): A-B—0.59; A-G—0.51; B-C—0.58; B-E—0.59; B-G—0.60; C-F—0.60; D-G—0.47; F-G—0.50. Similarly, the maximum contingency was found between the phenes: A-F—0.72; C-D—0.70; C-G—0.71; D-F—0.75; E-F—0.70.

Thus, among all the considered phenes (A, B, C, D, E, F, G) that form elytra pattern from yellow spots on a black background, it was found positive conjugate variability of medium to maximum value, indicating the coupled nature of inheritance of the signs.

Conclusions

The main conclusions include the following results:

1. In the examined population of beetles various aberrations in each of the fen, of which elytra pattern consists, were identified: A phene was presented in the 8 aberrations, phene B—10, phene C—7, phene D—10, phene E—8, phene F—13, and phene G—11 aberrations.

From them the highest frequency had aberrations in “Elabuga” population: A_2-A_8, B_1-B_1, C_1-C_6, D_1-A_2, E_6-E_4, F_1-F_1, G_9-G_3(G_{10}) on the left and right elytra, respectively; in “Muslyumovsky” population was: A_8-A_1, B_3-B_1, C_1-C_6, D_2-D_1, E_6-E_1, F_{12}-F_{12}, G_1-G_4. The lowest frequency of aberrations in the I population had: A_6 (A_7)-A_4, B_4 (B_7)-B_6(B_8), C_5-C_4, D_7-D_3, E_8-E_2, F_6(F_8)-F_{12}(F_{13};F_8), G_2-G_2(G_7) on the left and right elytra, respectively; in the II population, similar to: A_3-A_8, B_{10}- B_4(B_5), C_4-C_1(C_3;C_4), D_9-D_{10}, E_8-E_5, F_8(F_9)-F_4, G_2(G_7;G_8)-G_2(G_{11}).

2. Yellow spots on the black ladybugs elytra significantly tended to decrease in size, which indicates a slightly increased covers melanization in the studied beetle populations. In the both studied populations equal reduction of the size of the spots of the phenes A, B, D, G was observed. The maximum reduction in spots of phenes C, E was typical in the population of Elabuga district, spots of the phene F—in Muslyumovsky area.
3. Among all the compared signs of the left elytra pattern positive correlation was found (r_{xy} = 0.43-0.77), indicating the average and maximum conjugate variation. Maximum conjugate was found between phenes: A-B—0.71; A-F—0.69; B-D—0.81; B-F—0.77; D-F—0.77 in Elabuga district and between phenes: A-F—0.72; C-D—0.70; C-G—0.71; D-F—0.75; E-F—0.70 in Muslyumovsky area. These facts indicate the linked genotype inheritance of the considered features.

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