

Prospects of Using the Coccinellid *Harmonia axyridis* Pall. for Biological Plant Protection with Consideration of Its Feeding Preferences

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Abstract—The voracity and feeding preference index of larvae of the coccinellid multicolored Asian lady beetle *Harmonia axyridis* of six morphotypes differing in their elytral pattern are investigated. It is found that the morphotype of the lady beetle marks the feeding preferences of its larvae.

Key words: coccinellid *Harmonia axyridis*, elytral pattern, feeding preferences

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The predatory coccinellid multicolored Asian lady beetle *Harmonia axyridis* Pallas is used for protecting vegetable and green crops from aphids in greenhouses of the Primorskii krai and northwestern region of the Russian Federation [1, 2]. This species is widespread in Southeast Asia and Siberia [3] and in the past 10–15 years has acclimatized in Europe and North and South America [4]. This lady beetle is characterized by considerable ecomorphological intraspecific variability, one of the manifestations of which is the presence in natural populations of several stable morphotypes differing in elytral pattern (Fig. 1), behavioral characteristics, and reproductive indices [5, 6].

For understanding the factors that provided the rapid colonization of the multicolored Asian lady beetle on three continents as well as complete adjustment to its natural resources, we need detailed investigations of the ecophysiological characteristics of *H. axyridis* morphotypes and primarily their feeding preferences, an important criterion for evaluating an entomophage in biological methods of plant protection. Therefore, the purpose of the work was an evaluation of the feeding

preferences of *H. axyridis* larvae of different morphotypes. Larvae were selected as the object of investigations, since the Asian lady beetle is used in the larval stage in greenhouses.

METHOD

We used a laboratory culture of *H. axyridis* which was established from a sample of insects collected at overwintering sites in 2007 on the island of Cheju (33°10'N) in the southern part of the Korean Peninsula. The culture was maintained on common grain and peach aphids. Daily voracity was assessed on Asian lady beetle larvae from lines *aulica*, *axyridis*, *intermedia*, *spectabilis*, *conspicua SS*, *conspicua BS*, and *succinea*; the allele of their elytral pattern was preliminarily brought into a homozygous condition [7]. The experiment was conducted at 25°C, relative humidity 70–80%, and 18-h photoperiod. One first instar larva each was transplanted to a petri dish for the first day after hatching from eggs. During the first three days of the experiment, 20 wingless female aphids were placed



Fig. 1. Morphotypes of *Harmonia axyridis* differing in elytral pattern: (1) *succinea*; (2) *aulica*; (3) *intermedia*; (4) *axyridis*; (5) *spectabilis*; (6) *conspicua*.

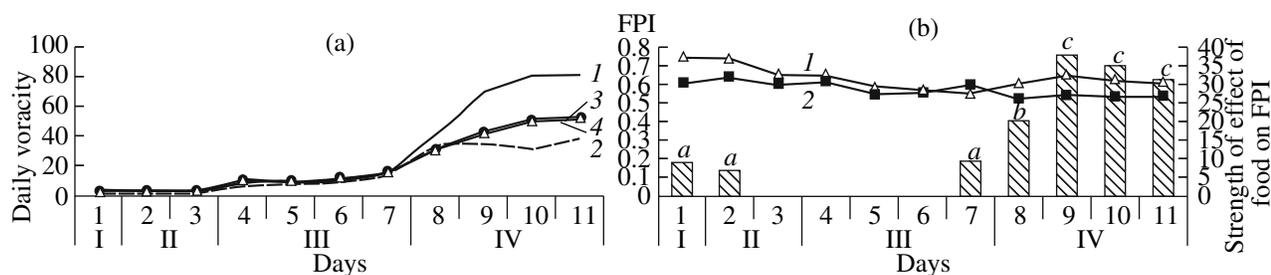


Fig. 2. Dynamics of daily voracity (a) of first–fourth (I–IV) instar larvae during feeding on a mixture of grain (1) and bean (2), peach (3) and bean(4) aphids and their feeding preference index (b) for grain (1) and peach (2) aphids; the letters above the columns denote variants in which the effect of food on FPI is significant: (a) $p < 0.05$; (b) $p < 0.01$; (c) $p < 0.001$.

daily in each dish. At older larval instars, the number of aphids was increased to 50–200 per day. We used two variants of food: a mixture of peach and bean (1) and grain and bean (2) aphids in a 1 : 1 ratio. Daily voracity was evaluated for 10–11 days before pupation of the larvae. The feeding preference index (FPI) of the predator was calculated by the formula $FPI = \ln(e_i/A_1)/[\ln(e_i/A_1) + \ln(e_2/A_2)]$, where A_1 and A_2 are the initial number of aphids of the first and second species that survived the day [8]. For statistical processes we used ANOVA, which was carried out with the SPSS v.13.0 statistical software package.

RESULTS AND DISCUSSION

Significant differences were revealed in the dynamics of daily voracity of larvae during feeding on different aphid species (Fig. 2, a). In the mixture of bean and grain aphids, the lady beetle preferred the grain aphid, which was displayed especially in larvae of the first two instars (FPR 0.65–0.75) as well as in the last fourth instar (Fig. 2, b). Larvae of older instars ate both aphid species in equal amounts (Fig. 2, a), whereas first–second instar larvae ate the peach aphid more often (FPI 0.60–0.63), Fig. 2, b.

Larvae of younger instars were limited in the choice of prey. The aphid should correspond to the size of the predator, which in the first two larval instars didn't exceed 3 mm in length (Table 1). The smaller the aphid, the more available it is for eating by young larvae. In our experiment, the smallest was the grain aphid whose body length was 1.5–1.8 times less than that of first–second instar larvae. Bean and peach aphids are equal in size to first instar larva, which makes it difficult for the predator to catch and hold its prey. We can assume that the pronounced preference for the grain aphid by larvae of younger instars is due primarily to its small size.

In variant 1, both peach and bean aphids had a similar body length but differed substantially in weight: the peach aphid on average weighed half as much as the bean aphid, respectively 0.49 and 1.09 mg. In connection with this, larvae of younger instars more willingly ate the peach aphid.

Older instar larvae are 3–6 times larger than aphids (Table 1). Therefore, their preference is determined not by the size or weight of the prey but by the nutritive value of food and time that must be spent on pursuing, catching, and eating. In conformity with the theory of optimal procurement of food, the predator strives to increase maximally the rate of obtaining energy; in this case, the advantage of the prey is equal to E_i/h_i , where E_i is the energy content (nutritive content) and h_i is the time of processing the prey [9].

No feeding preferences were noted in third instars of the Asian lady beetle. According to the ANOVA results, in this period FPI didn't depend on the aphid species. At the same time, in the fourth instar the feeding factor had a high significant ($p < 0.001$) effect on the index, the strength of which was 30–35%, which is three times higher than in younger larval instars (Fig. 2, b). Such a substantial difference emphasizes the differences in mechanisms determining the feeding preferences in younger and older instar larvae. At the start of larval development, feeding preferences depend on the size and weight of the prey and at the end they are determined primarily by its nutritive value. The third instar is an intermediate stage, during which the individual utilizes the available food resource and forms from the accessible prey a ration that provides maximum intake of energy with minimum expenditure of effort and time.

The differences between morphotypes in FPI were revealed only for larvae from line *intermedia*, in which feeding preference for the grain aphid was clearly expressed in the third instar (Fig. 3, a). The FRI for the peach aphid in larvae gradually decreased during development and by the fourth instar approached 0.5 (Fig. 3, b),

Table 1. Ratio of sizes of different instar coccinellid larvae and aphids

Aphid		Instar			
species	body length, mm	I	II	III	IV
Bean	1.8–2.5	1 : 1.1	1 : 1.4	1 : 2.8	1 : 4.4
Peach	2.0–2.5	1 : 1.0	1 : 1.3	1 : 2.7	1 : 4.2
Grain	1.2–2.0	1 : 1.5	1 : 1.8	1 : 3.8	1 : 5.9

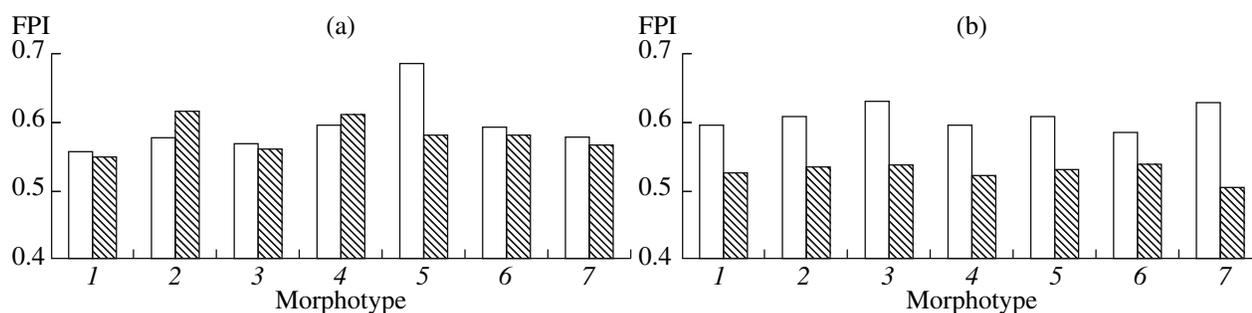


Fig. 3. Feeding preference index of third (a) and fourth (b) larval instars from lines respectively *aulica* (1), *axyridis* (2), *conspicua BS* (3), *conspicua SS* (4), *intermedia* (5), *spectabilis* (6), and *succinea* (7); first column, grain aphid; second column, peach aphid.

which indicated the equal nutritive value of both aphid species, despite their twofold difference in weight.

With equal voracity of larvae, the biomass of the bean aphid being consumed by them was twice greater than that of the peach aphid (Table 2). A similar ratio of weight was noted in the case of the larvae feeding on one aphid species. Consequently, the peach aphid exceeds the bean aphid in nutritive value per unit weight by two times.

When feeding on a mixture, larvae from the lines *conspicua BS* and *conspicua SS* consumed the greatest amount of aphids both in number and weight (Table 2). These are morphologically close morphotypes which differ only in the size of the light spot on the elytra (Fig. 1). The similarity of the elytral pattern is combined with close values of biomass needed by the larva to complete development. ANOVA showed that the effect of the morphotype on biomass consumption by larvae is highly significant ($p < 0.001$), and the strength of the effect of this factor is about 40–60% depending on the aphid species (Table 2).

We assume that the morphotype of the multicolored Asian lady beetle marks certain ecophysiological characteristics. The elytral pattern is determined by a series of multiple alleles of one gene [10], which can be linked with a set of hereditary factors responsible for

voracity and feeding preferences. Our separating out the phenotypic marker into a homozygote enhanced the manifestation of its linked genes determining increased voracity of larvae from lines *conspicua BS* and *conspicua SS* when feeding on a mixture of aphids.

The data presented allow making a number of conclusions concerning the prospects of using the multi-color Asian lady beetle for protecting plants from aphids. Small aphid species (up to 1.5–2 mm) are most preferable for younger instar larvae, which are usually released in greenhouses for suppressing centers of the pest. The cotton aphid is among the most harmful aphid species belonging to this class. Adults of large aphid species (potato aphid, rose-grain aphid) are accessible only for third and fourth instar larvae. It is necessary to correct the method of using the Asian lady beetle depending on the aphid species against which the release of the aphidophage is directed. When using the lady beetle against large aphid species, it is necessary to take into consideration that the young predator will eat primarily larvae of the pest accessible in size, and at the same time female aphids are continuing to reproduce. The release of larvae after molting in the third instar, when the size of the predator allows it to cope with practically any aphid species and the possibilities of

Table 2. Consumption of biomass (mg) by coccinellid larvae during feeding on bean and peach aphids

Morphotype	Feeding on two aphid species			Feeding on one aphid species		
	bean	peach	weight ratio	bean	peach	weight ratio
<i>Axyridis</i>	233.3 ± 7.9	110.6 ± 2.3	2.11	423.2 ± 6.0	194.0 ± 5.7	2.18
<i>Succinea</i>	234.4 ± 8.6	108.2 ± 2.5	2.17	402.9 ± 6.3	198.2 ± 6.4	2.03
<i>Aulica</i>	220.2 ± 19.2	102.7 ± 5.6	2.14	–	–	–
<i>Conspicua BS</i>	263.8 ± 6.8	123.8 ± 2.0	2.13	–	–	–
<i>Conspicua SS</i>	242.9 ± 7.9	113.4 ± 2.3	2.14	–	–	–
<i>Intermedia</i>	222.6 ± 6.8	106.3 ± 2.0	2.09	–	–	–
<i>Spectabilis</i>	222.2 ± 6.8	107.2 ± 2.0	2.07	–	–	–
Strength of morphotype effect, %	42.90	61.50	–	27.90		–
Significance	$p < 0.001$	$p < 0.001$	–	$p < 0.01$		–

moving and searching for the pest increase considerably, can be the solution to the problem.

The data obtained confirmed the hypothesis put forth earlier in the literature that the elytral pattern gene of the multicolored Asian lady beetle is linked with a set of hereditary factors determining the ecophysiological characteristics of the aphidophage, including its feeding preferences. This gives ground for forming type cultures of *H. axyridis* which will most completely reflect and preserve genotypic variability characteristic of the species during long breeding in the laboratory. Underlying the proposed method is the use of the elytral pattern as a phenotypic marker. Singling out the marker into a homozygote will allow controlling its linked genes determining feeding preferences and reproductive and behavioral characteristics inherent to different morphotypes of the lady beetle. When necessary, these type cultures of the lady beetle will serve as the parent material for breeding *H. axyridis* with prescribed characteristics, for example, with increased voracity when feeding on a certain aphid species.

REFERENCES

1. Yarkulov, F.Ya. and Belyakova, N.A., Ecological Basis of Biological Protection of Greenhouse Plants, *Zashch. Karan. Rast.*, 2007, no. 1.
2. Kozlova, E.G., Biological Protection of Green Crops during Cultivation of Lettuce Lines, *Gavrish*, 2008, no. 9.
3. Kuznetsov, V. N., *Zhuki-koktsinellidy (Coleoptera: Coccinellidae) Dal'nego Vostoka Rossii* (Coccinellid Beetles (Coleoptera: Coccinellidae) of the Russian Far East), Vladivostok: Dal'nauka, 1993, part 2.
4. Soares, A.P., Borges, I., Borges, P.A., Labrie, G., and Lucas, E., *Harmonia axyridis*: What Will Stop the Invader?, *BioControl*, 2008, vol. 53, pp. 127–145.
5. Soares, A.O., Coderre, D., and Schanderl, H., Influence of Prey Quality on the Fitness of Two Phenotypes of *Harmonia axyridis* adults, *Entom. Exp. Appl.*, 2005, vol. 114, no. 3.
6. Seo, M.J., Kim, G.H., and Youn, Y.N., Differences in Biological and Behavioral Characteristics of *Harmonia axyridis* (Coleoptera: Coccinellidae) According to Color Pattern of Elytra, *J. Appl. Entomol.*, 2008, vol. 132, pp. 239–247.
7. Belyakova, N.A. and Balueva, E.N., Prospects of Using Polymorphic Cultures and Maleless Lines of *Harmonia axyridis* Pall. For Biological Plant Protection, *Inform. Byull. VPRS MOBB*, 2007, no. 38.
8. Manly, B.F.J., Miller, P., and Cook, L.M., Analysis of Selective Predation Experiment, *Am. Nat.*, vol. 106, pp. 719–736.
9. Begon, M., Harper, J., and Townsend, C., *Ecology: Individuals, Populations, and Communities*, Oxford: Blackwell, 1986.
10. Tan, C.C., Mosaic Dominance in the Inheritance of Color Patterns in the Lady-Bird Beetle, *Harmonia axyridis* (Pallas), *Genetics*, 1946, vol. 31, no. 1.