

THE FEATURES OF BIOLOGY OF *HARMONIA AXYRIDIS* PALL. AND THE MOST COMMON SPECIES OF COCCINELLIDS IN UKRAINE AGROCOENOSIS

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Abstract

The research was conducted in 2017–2019 years in the Institute of Plant Protection of The National Academy of Agrarian Sciences of Ukraine in the Laboratory of entomology and resistance of agricultural crops against pests (Kyiv, Ukraine).

The objective of the research is investigation of particular biology features of *Harmonia axyridis* Pall. in comparison with the main species of coccinellids in typical agrocoenosis. The research methods are the following: laboratory method that means laboratory maintenance of coccinellids; mathematical-statistical method that means statistical processing of the obtained results.

The Coccinellidae family (Latreille, 1807) has an important economic value in the human business activities. Most species are predators of aphids, scale insects, thrips, spider mites, leafhoppers, whiteflies, eggs and larvae of other small arthropods. Coccinellids are marked by their high gluttony, polyphagous, fertility. Beetles and larvae of ladybirds play a significant role in the quantity control of pests of agricultural, forest and ornamental plants.

Since 2009 researchers in Ukraine have devoted great attention to identification and distribution of invasive species of Asian lady beetle, or Multicolored Asian lady beetle, Harlequin ladybird, Halloween ladybeetle (*Harmonia axyridis* Pallas, 1773). *H. axyridis* Pall. is characterized by its wide ecological plasticity, trophic specialization, greater gluttony, fertility and number of generations leading to the gradual displacement of local species of coccinellids.

The comparative results of researches of some biology features of *H. axyridis* Pall. and the most common species of ladybirds are presented. The survival of coccinellids imago during the wintering, in the active period in the absence of feed, their gluttony for different species of aphids is examined. Features of oviposition and duration of various stages of coccinellids development are presented.

In the laboratory the Asian lady beetle was marked among other species by the number of its laid eggs, oviposition period, duration of various stages of its development, survival and gluttony.

Keywords: ladybirds, oviposition, stage, wintering, aphids, development, feeding, local species, Asian lady beetle, species-invader.

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1. Introduction

Among representatives of the Coccinellidae (Coleoptera) family during the last 20 years special attention has been devoted to Asian lady beetle. The original habitat of this insect is located in Central and Southeast Asia. Today *H. axyridis* Pall. is recognized as the «most aggressive ladybird on Earth», mass eurytopic species-invader, that exists on four continents [1].

For a long time, Asian lady beetle was successfully bred and used against aphids and scale insects, pests of agriculture and forestry. In the USSR this began in 1927 (Georgia, Belarus, Kazakhstan [2]; in Ukraine – since the 1960s. [3]), in Western Europe – since 1982. Gradually *H. axyridis* Pall. acclimatized in nature and started to form stable, rapidly growing populations.

Since 1991 in Western Europe were single exemplars of Asian lady beetle (France, Greece, Germany, Belgium, the Netherlands). Since 2002 mass reproduction and displacement across Europe has begun [2, 4–8].

The first natural populations of Harlequin ladybird in Ukraine were discovered in 2009 [9, 10]. Since then ladybird has been spreading rapidly in Ukraine. Identification and distribution of *H. axyridis* Pall. are marked in many publications [11–21] etc.

Besides the useful value in biological plant protection, the Asian lady beetle invasion has negative consequences. *H. axyridis* Pall. destroys harmless insects in agrocoenosis and natural communities, displaces local species of ladybirds, becomes a pest of fruit-growing and winemaking, as it damages apples, pears, citrus fruits, grapes [22]. Imagines form masses, swarmed in residential buildings in the autumn-winter period. Beetles can bite people and cause allergic reactions. In the USA Harlequin ladybird is recognized as a new pest of bee-keeping [23].

The objective of the research is investigation of particular biology features of *Harmonia axyridis* Pall. in comparison with the main species of coccinellids in typical agrocoenosis.

2. Materials and Methods

The research was conducted in 2017–2019 years in the Institute of Plant Protection of The National Academy of Agrarian Sciences of Ukraine in the Laboratory of entomology and resistance of agricultural crops against pests (Kyiv, Ukraine).

In the laboratory were studied four species of coccinellids: seven spot ladybird, *Coccinella septempunctata* Linnaeus, 1758; variegated lady beetle, *Hippodamia variegata* Goeze, 1777; fourteen spot ladybird, *Propylea quatuordecimpunctata* Linnaeus, 1758; *Harmonia axyridis* Pall.

The laboratory maintenance of ladybirds was conducted by the methodology of G.I. Savoyskaya [24, 25]. Coccinellids were kept in containers at temperatures of +22.0–24.0 °C (during wintering at temperatures of +4.0 °C), relative humidity of 60.0–70.0 %, photoperiod of 17 hours/24. For imago feeding the following species of aphids were used: pea aphid, *Acyrtosiphon pisum* Harris, 1776; wheat aphid, *Schizaphis graminum* Rondani, 1852; beet leaf aphid, or bean aphid, *Aphis fabae* Scopoli, 1763; cabbage aphid, *Brevicoryne brassicae* Linnaeus, 1758. Every day aphids were put in containers with coccinellids, later their quantity left was counted, and the number of aphids that were eaten per day was calculated.

3. Results and Discussion

There were examined features of oviposition, duration of development of various stages, imago survival during the wintering and in the period of active development in the absence of feed, as well as feeding females, males and fourth instar larvae with different species of aphids.

The oviposition of seven spot ladybird started on May 18 and terminated on July 15; its duration was 34–56 days. The pause between separate ovipositions reached up to four days. The number of eggs in one cluster amounted to 6–86. The fertility within the whole period was 608–1381 eggs, the number of clusters was 20–38.

The oviposition of variegated lady beetle lasted 25–43 days, its beginning was marked on May 27, the end was on July 13. The fertility of one female was 282–566 eggs; the number of clusters ranged from 17 to 28, the number of eggs in one cluster was between 5 and 51. The egg-laying interval was from one to five days.

The oviposition of fourteen spot ladybird was marked from May 21 to July 13. During 32–54 days females laid from 358 up to 574 eggs. The number of eggs in one cluster ranged from 6 to 45; the number of clusters was 20–33, with an interval between ovipositions from one to four days.

The fertility of Asian lady beetle was 811–1645 eggs, the minimum number of eggs laid was 8 and the maximum was 67. The number of clusters was 20–42, pause between ovipositions was from one to three days. The beginning of oviposition was marked on May 18, the end – on July 17, its duration was 39–56 days.

The oviposition dynamics of coccinellids of overwintered generation is presented in Table 1.

Table 1

The oviposition dynamics of coccinellids, 2017–2019

Species	Number of eggs		Number of clusters		Mean number of eggs in one cluster	Mean duration of oviposition, days
	total	mean	total	mean		
<i>C. septempunctata</i> L.	18830	941.5	581	29.1	32.4	47.5
<i>H. variegata</i> Gz.	8527	426.4	432	21.6	19.7	34.1
<i>P. quatuordecimpunctata</i> L.	9261	463.1	514	25.7	18.0	41.0
<i>H. axyridis</i> Pall.	25894	1294.7	636	31.8	40.7	49.4
LSD ₀₅	–	116.2	–	3.2	2.0	3.9

Among all ladybirds species, *H. axyridis* Pall. differed by its fertility and mean number of eggs in one cluster. At the same time the mean number of its clusters and duration of oviposition were similar to *C. septempunctata* L.. The lowest fertility, number of clusters and duration of oviposition were observed in case of *H. variegata* Gz., but the mean quantity of its eggs in one cluster prevailed *P. quatuordecimpunctata* L..

For ladybirds breeding each oviposition was placed in a separate container, where hatching of eggs larvae was kept together. And then from each container one larva was transferred to another separate container for its individual keeping. Thus, at the same time and conditions larvae developed both in common and separate containers. A noteworthy detail was that ladybirds in case of individual breeding passed the full cycle of development faster.

General maintenance. The development of *C. septempunctata* L. eggs lasted 2–4 days, larvae – 14–17 days, pupae – 4–6 days; full cycle – 21–26 days. The duration of *H. variegata* Gz. eggs development was 2–4 days, larva – 9–13 days, pupa – 3–5 days; the entire cycle was completed in 15–20 days. *P. quatuordecimpunctata* L. eggs developed within 2–4 days, larvae – 8–12 days, pupae – 3–4 days; the complete cycle lasted for 14–20 days. The development of *H. axyridis* Pall. eggs took 2–4 days, larvae – 13–21 days, pupae – 3–5 days; the total egg-to-imago period was 19–30 days.

The mean duration of the developmental stages of coccinellids of the overwintered generation (general maintenance) is presented in **Table 2**.

Table 2

The duration of the developmental stages of coccinellids, days, 2017–2019

Species	Stage of development			Full cycle of development
	egg	larva	pupa	
<i>C. septempunctata</i> L.	3.1	15.4	4.9	23.4
<i>H. variegata</i> Gz.	3.0	10.7	3.7	17.4
<i>P. quatuordecimpunctata</i> L.	3.0	10.0	3.5	16.5
<i>H. axyridis</i> Pall.	3.0	16.7	4.0	23.7
LSD ₀₅	0.2	0.5	0.2	0.7

In case of general maintenance all species of coccinellids had the similar duration of their egg stage, the larval stage was similar for seven spot ladybird and Asian lady beetle, variegated lady beetle and fourteen spot ladybird. *C. septempunctata* L. differed among others by duration of pupa stages. In general, the full development cycle was similar for *C. septempunctata* L. and *H. axyridis* Pall., in *H. variegata* Gz. and *P. quatuordecimpunctata* L..

Individual maintenance. The first instar larvae of seven spot ladybird developed in 2–3 days, the second – in 1–3 days, the third – in 2–3 days, the fourth – in 3–5 days; pupae – in 3–5 days. The

complete development cycle lasted 15–19 days. The duration of the first instar larva of variegated lady beetle was 2–4 days, of the second – 2–3 days, of the third – 2–3 days, of the fourth – 2–4 days; of the pupae – 3–4 days. The entire cycle continued 14–18 days. In case of fourteen spot ladybird the development of the first instar larvae lasted 2–3 days, of the second – 2–3 days, of the third – 1–3 days, of the fourth – 2–4 days; of the pupae – 3–4 days, and the cycle generally ranged from 13 to 17 days. And the development of the first instar larvae of Asian lady beetle continued during 2–3 days, of the second – 1–3 days, of the third – 2–3 days, of the fourth – 4–5 days; of the pupae – 3–5 days. The duration of the complete cycle was 17–21 days.

The mean duration of the developmental stages of ladybirds of overwintered generation is presented in **Table 3** (individual maintenance).

Table 3

The duration of the developmental stages of coccinellids, days, 2017–2019

Species	Stage of development						Full cycle of development
	egg	larva				pupa	
		1st instar	2nd instar	3rd instar	4th instar		
<i>C. septempunctata</i> L.	3.1	2.1	2.1	2.2	3.5	3.5	16.5
<i>H. variegata</i> Gz.	3.0	2.6	2.1	2.4	2.9	3.1	16.1
<i>P. quatuordecimpunctata</i> L.	3.0	2.3	2.1	2.0	2.5	3.0	14.9
<i>H. axyridis</i> Pall.	3.0	2.5	2.0	2.1	4.8	3.9	18.3
LSD ₀₅	0.2	0.1	0.1	0.1	0.2	0.1	0.4

In case of individual maintenance the first instar larvae of *C. septempunctata* L. developed most rapidly, the second instar larvae of all species developed similarly, the third instar larvae of *H. variegata* Gz. differed by duration, the fourth instar larvae of *H. axyridis* Pall. was slightly prevalent by its period of larvae development. The pupa stage lasted longer for Asian lady beetle, a little less for seven spot ladybird and it was almost identical for variegated lady beetle and fourteen spot ladybird. The full cycle of development was marked as similar for *C. septempunctata* L. and *H. variegata* Gz., faster for *P. quatuordecimpunctata* L. and the longest for *H. axyridis* Pall..

During 2017–2019 years in the wintering period were annually kept 200 exemplars of coccinellids imago (**Table 4**). The diapausing lasted from the first decade of November to the third decade of March.

In the wintering period of 2017–2019 among the researched species of coccinellids, Asian lady beetle was marked by its highest survival with percentage of mortality on the level of 25.3. The mortality of other species was on the following levels: seven spot ladybird – 38.7 %, fourteen spot ladybird – 53.3 %, variegated lady beetle – 70.0 %.

To determine the ability of ladybirds to tolerate adverse conditions, in particular absence of food, beetles were kept in containers until complete death. The percentage of mortality is presented in **Table 5**.

In the absence of food the highest survival was observed for *H. axyridis* Pall. – up to 40 days, the lowest for *H. variegata* Gz. – up to 15 days, *C. septempunctata* L. – up to 30 days, *P. quatuordecimpunctata* L. – up to 20 days.

This feature of *H. axyridis* Pall. biology allows it to withstand periods of insufficient feed or absence of food. And therefore this helps to hold the quantity of the population and promotes its rapid growth after feeding (because of the high fertility of Asian lady beetle).

The mean numbers of aphids, eaten per day by females, males and fourth instar larvae, are presented in **Table 6**.

Table 4

The wintering of coccinellids in the laboratory

Years	Species	Quantity of imago, exemplars		Mortality, %
		on wintering	dead	
2017	<i>C. septempunctata</i> L.	50	21	42.0
2018		50	17	34.0
2019		50	20	40.0
2017	<i>H. variegata</i> Gz.	50	41	82.0
2018		50	33	66.0
2019		50	31	62.0
2017	<i>P. quatuordecimpunctata</i> L.	50	27	54.0
2018		50	30	60.0
2019		50	23	46.0
2017	<i>H. axyridis</i> Pall.	50	16	32.0
2018		50	10	20.0
2019		50	12	24.0
LSD ₀₅		–	–	13.8

Table 5

The mortality of coccinellids imago in the absence of food

Species	The mortality of imago, %							
	5th day	10th day	15th day	20th day	25th day	30th day	35th day	40th day
<i>C. septempunctata</i> L.	30.0	16.0	22.0	0	8.0	24.0	0	0
<i>H. variegata</i> Gz.	38.0	34.0	28.0	0	0	0	0	0
<i>P. quatuordecimpunctata</i> L.	36.0	22.0	32.0	10.0	0	0	0	0
<i>H. axyridis</i> Pall.	24.0	20.0	0	6.0	0	26.0	10.0	14.0

Among investigated species of ladybirds, the Asian lady beetle was characterized by the greatest gluttony, that was close to the quantity of aphids, eaten by the seven spot ladybird. The quantity of feed, eaten by the variegated lady beetle and the fourteen spot ladybird, was marked as similar, with some excess in case of the males of the latter one. Similarly larvae were fed with aphids, but *H. variegata* Gz. prevailed *P. quatuordecimpunctata* L. by the quantity of eaten food.

As these ladybirds are main representatives of coccinellids fauna in typical agrocoenosis, such gluttony of *H. axyridis* Pall. promotes significant competition in the food chains with local species of ladybirds.

Among the available aphids, beetles and larvae of coccinellids preferred *S. graminum* Rond., the least eaten was *A. pisum* Harr., and the quantity of eaten *A. fabae* Scop. and *B. brassicae* L. varied. Females of *C. septempunctata* L. preferred cabbage aphid, males and larvae – bean aphid. Imago and larvae of *H. variegata* Gz., *P. quatuordecimpunctata* L., *H. axyridis* Pall. (except larvae of fourteen spot ladybird.) ate more cabbage aphid.

The limitation of the study is that only three main indigenous species of ladybirds: *C. septempunctata* L., *H. variegata* Gz. and *P. quatuordecimpunctata* L. are presented in the article.

The further researches of the biological features of *H. axyridis* Pall in comparison with the other local species of coccinellids are promising. Due to which it is possible to determine the species of ladybirds, the quantity of which will be rapidly reduced in the case of mass reproduction of *H. axyridis* Pall.

Table 6

The gluttony of coccinellids imago and larvae, 2019

Species of coccinellids	Species of aphids	Average quantity of aphids eaten per day, exemplars		
		female	male	4th instar larvae
<i>C. septempunctata</i> L.	<i>S. graminum</i> Rond.	124.8	93.5	112.0
	<i>A. pisum</i> Harr.	89.0	61.3	81.5
	<i>A. fabae</i> Scop.	116.5	87.3	107.3
	<i>B. brassicae</i> L.	118.3	85.0	96.0
<i>H. variegata</i> Gz.	<i>S. graminum</i> Rond.	94.5	66.5	85.3
	<i>A. pisum</i> Harr.	60.3	36.5	49.0
	<i>A. fabae</i> Scop.	76.0	47.8	62.5
	<i>B. brassicae</i> L.	82.5	59.3	67.0
<i>P. quatuordecimpunctata</i> L.	<i>S. graminum</i> Rond.	85.8	69.3	73.8
	<i>A. pisum</i> Harr.	58.5	41.3	46.5
	<i>A. fabae</i> Scop.	79.5	57.5	61.8
	<i>B. brassicae</i> L.	83.3	62.8	59.3
<i>H. axyridis</i> Pall.	<i>S. graminum</i> Rond.	142.5	110.8	127.5
	<i>A. pisum</i> Harr.	113.8	87.3	98.0
	<i>A. fabae</i> Scop.	129.5	103.8	121.3
	<i>B. brassicae</i> L.	134.3	104.5	123.8
Standard deviation		26.4	23.1	27.2

The research is useful in the biological protection of plants where *H. axyridis* Pall. is the most effective entomophage among coccinellids, but also has a negative effect on them.

4. Conclusions

In case of laboratory maintenance of coccinellids the fertility of *H. axyridis* Pall. was the greatest – 1294.7 eggs, for other species it reached: *C. septempunctata* L. – 941.5, *H. variegata* Gz. – 426.4, *P. quatuordecimpunctata* L. – 463.1. The mean number of eggs in one cluster was also higher than in other ladybirds, namely: *H. axyridis* Pall. – 40.7, *C. septempunctata* L. – 32.4, *P. quatuordecimpunctata* L. – 18.0, *H. variegata* Gz. – 19.7. The minimum number of eggs, laid by one female per day, was 5–8, the maximum was the following: seven spot ladybird – 86, variegated lady beetle – 51, Asian lady beetle – 67, fourteen spot ladybird – 45. *C. septempunctata* L. and *H. axyridis* Pall. had the greatly longer egg-laying period – 47.5 and 49.4 days, while *H. variegata* Gz. – 34.1, *P. quatuordecimpunctata* L. – 41.0. Similarly *C. septempunctata* L. and *H. axyridis* Pall. prevailed by the mean number of oviposition – 29.1 and 31.8, compared with *H. variegata* Gz. – 21.6, *P. quatuordecimpunctata* L. – 25.7.

The full cycle of coccinellids development in case of general maintenance passed longer than for individual and continued: *C. septempunctata* L. – 23.4 and 16.5 days, *H. variegata* Gz. – 17.4 and 16.1 days, *P. quatuordecimpunctata* L. – 16.5 and 14.9 days, *H. axyridis* Pall. – 23.7 and 18.3 days.

The greatest gluttony was observed in imago and larvae of Asian lady beetle, in particular, when fed by wheat aphid: females – 142.5, males – 110.8, fourth instar larvae – 127.5 exemplars/day. All species of coccinellids ate less pea aphid, especially fourteen spot ladybird: females – 58.5, fourth instar larvae – 46.5 exemplars/day, males of variegated lady beetle – 36.5 exemplars/day.

As a result of this research, Asian lady beetle was marked with its high survival both during the wintering (25.3 %) and the active period (up to 40 days).

These as well as other features of *H. axyridis* Pall. biology promote faster quantity recovery and even growth of its population in comparison with local species of ladybirds.

Conflict of interest

There are no competing interests in the article.

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