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On the feeding of the potato ladybird beetle *Henosepilachna vigintioctomaculata* Motschulsky, 1858 (Coleoptera: Coccinellidae) on wild plants in Primorskii krai, Russia

К вопросу о питании картофельной коровки *Henosepilachna vigintioctomaculata* Motschulsky, 1858 (Coleoptera: Coccinellidae) на дикорастущих растениях в Приморском крае

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Key words: potato ladybird beetle, wild plants, feeding, Primorskii krai.

Ключевые слова: картофельная коровка, дикоросы, питание, Приморский край.

Abstract. Experimental data on the feeding habits of the potato ladybird beetle, *Henosepilachna vigintioctomaculata* Motschulsky, 1858 on wild plants in Primorskii krai of Russia, revealed a strong influence of the food quality on its survivability. *Solanum tuberosum* L., 1753 and *Thladiantha dubia* Bunge, 1833 were found to be the most beneficial food sources for the insect.

Резюме. Приведены сведения об особенностях питания *Henosepilachna vigintioctomaculata* Motschulsky, 1858 на дикорастущих растениях в Приморском крае. Полученные данные свидетельствуют о глубоком воздействии качества пищи на жизнеспособность картофельной коровки. Наиболее благоприятным кормом в экспериментах оказались *Solanum tuberosum* L., 1753 и *Thladiantha dubia* Bunge, 1833.

The feeding specialization of the potato ladybird beetle generates significant theoretical and practical interest because changes in the population size and habitat range of the pest often depend on changes in its diet. Previous studies [Ermak et al., 2002] report a long history of the potato ladybird beetle in Primorsky krai. The collection of the Zoological institute (Russian Academy of Sciences) contains the specimens of *Henosepilachna vigintioctomaculata* Motschulsky, 1858, that were collected in the upper reaches of the Montugai river (Barabashevka) by Khristinich in 1894 as well as in Vladivostok in 1909, in the valley of the Iman river (Bolshaya Ussurka) in 1911, and in Shkotovo in 1916. However, the locals believe that the potato ladybird beetle was brought to Primorsky krai during the Japanese Siberian Intervention [Petina, 1951].

According to some studies, the potato ladybird beetle is a polytrophic pest that feeds on many agricultural crops besides the nightshades and cucurbits. For example, A.I. Kurentsov studied harmful insect species in the forests of the Russian Far East for many years and noted that potato ladybird beetles damaged leaves of various trees (*Aralia elata*, the Chinese angelica-tree; *Juglans mandshurica*, the Tigernut; *Phellodendron amurense*, the Amur cork tree; *Crataegus maximowiczii*, the hawthorn of Maksimovich; and *Vitis amurensis*, the Amur grape) and herbaceous plants (*Chrysosplenium alternifolium*, the alternate-leaved golden-saxifrage) [Kurentsov, 1953]. V.L. Lyubarskii reported a considerable damage caused by potato ladybird beetles to leaves of the *Aralia elata* and the *Juglans mandshurica* in Peishula, Shkotovsky district [Ivanova, 1962]. A.I. Ivanova showed that potato ladybird beetles could develop normally only on the burdock *Arctium lappa*. When beetles were fed the *Aralia elata*, the *Phellodendron amurense*, the *Juglans mandshurica*, the *Crataegus maximowiczii*, and apple tree in rearing cages only minor damage was observed on some leaves [Ivanova, 1961.]. According to Ivanova, larvae of the potato ladybird beetle were found on two wild plant species, *Thladiantha dubia*, the Manchu tubergourd, and *Solanum dulcamara*, the bittersweet. However, it remains unclear whether these plant species play an important role in the diet of the potato ladybird beetle. This determined the goal of our research.

Materials and methods

The laboratory colony of *Henosepilachna vigintioctomaculata* (Motschulsky) was created in 2019 by the Laboratory of Breeding and Genetic Research on Field Crops at the Federal Scientific Centre of Agricultural Biotechnology of the Far East named after A.K. Chaiki. Adult beetles (ten imagines of different sexes) were collected at various sites in Primorsky krai (Russia). To be introduced into the insectarium culture, the insects were collected in their natural environment, on linden *Tilia amurensis*, bird cherry

Padus asiatica, potato *Solanum tuberosum*, tomato *Solanum lycopersicum*, and eggplant *Solanum melongena*. Egg masses and larvae of different instars were selected as well. The first batch of insects was collected in 2019 and after that eight laboratory generations were reared. To maintain the polymorphism of the lines, new insects collected in nature were introduced into the culture in 2020 and 2021.

To study the morphometric characteristics of the potato ladybird beetle, 25 insects at different developmental stages (from larva to imago) were used for each variant. The length and width of eggs, larvae at different instars, and pupae as well as the length and width of the head, thorax, and elytra of imagines were measured using a stereo microscope Nikon SMZ25 and the software NIS-Elements. Before the launch of our experiment, fresh egg masses were collected from leaves of fodder plants. The egg masses were kept in Petri dishes on filter paper and moistened if necessary. The eggs were monitored during the incubation period to record the hatching rate of the lines. The emerged larvae were divided right after the emergence and placed in the batches of ten into 80 ml glass containers covered with cotton sheeting. The larvae were fed fresh leaves of fodder plants every day. The experiment was performed before the emergence of adult beetles. The following data were recorded in each experimental variant: the duration of the larval stage and each instar, of the prepupa and pupa stages, of the reproductive phases (for female beetles – time until and after oviposition and the duration of oviposition), and the total duration of the ontogeny. To calculate the survival rate of larvae and the emergence rate of adult beetles, the larvae were divided in six groups of 25 insects each and fed the main fodder plants of the 28-spotted potato ladybird in Primorsky krai: egg plant *Solanum melongena*, tomato *Solanum lycopersicum*, cucumber *Cucumis sativus*, squash *Cucurbita pepo*, potato *Solanum tuberosum*, linden *Tilia amurensis*, the Manchu tubergourd *Thladiantha dubia*, the Chinese angelica-tree *Aralia elata*, the Amur cork tree *Phellodendron amurense*, the hawthorn of Maksimovich *Crataegus maximowiczii*, the Amur grape *Vitis amurensis*, the alternate-leaved golden-saxifrage *Chrysosplenium pilosum*, and the burdock *Arctium lappa*. The obtained adult beetles were let to mate and divided after the mating to evaluate the fecundity of the females. The growth rate and constant, the duration of the incubation period and the post-reproductive stage were analysed using TWOSEX [Chi, 2016]. The experiment consisted of two parts. The first part that included eggplant, cucumber, squash, potato, and linden was published earlier [Matsishina et al., 2021]. The obtained data were statistically processed and compared employing Student's *t*-test. Differences between the parameter values were considered confident at $p \leq 0.05$. The data are presented as the mean and standard deviation ($x \pm Sx$).

The present work is registered in ZooBank (www.zoobank.org) under urn:lsid:zoobank.org:pub:717B13F7-7A1D-49D3-9F46-A3446C88092B.

Results and discussion

The potato ladybird beetle damages only leaves of plants. In our research, insects were not observed to feed on flowers, ovaries or fruits. The main fodder plant of the pest is potato. Adult beetles and larvae eat the

Figs 1–2. Feeding of potato ladybird beetles on potato plants. 1 — ladybird imagoes on potato leaf; 2 — leaf damage after ladybird imago feeding.

Рис. 1–2. Питание картофельной коровки на картофеле. 1 — имаго на листьях картофеля; 2 — скелетированные листья картофеля в результате питания коровки.

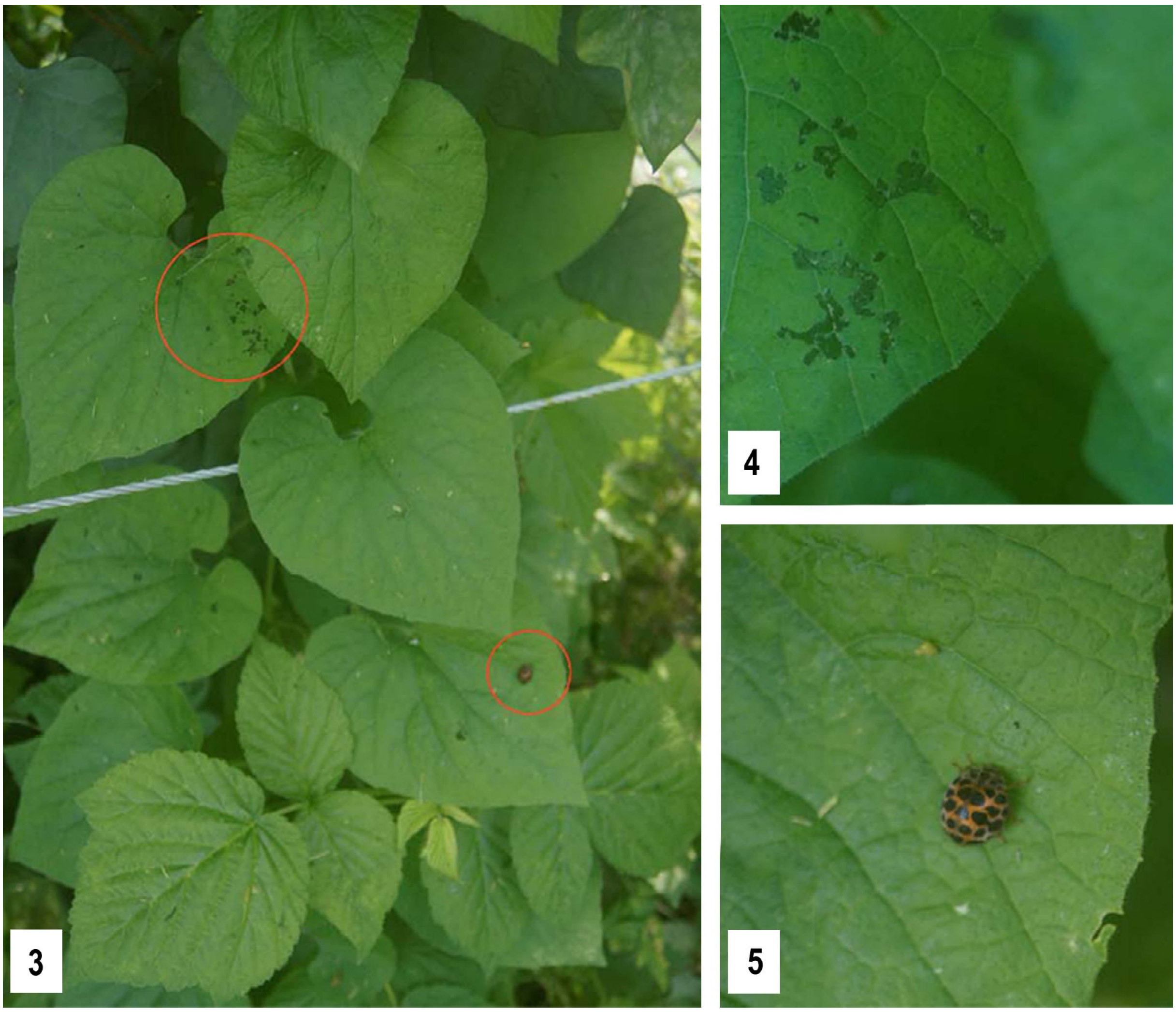
mesophyll tissue leaving veins intact (Figs 1–2). Despite the research data presented by A. Ivanova [Ivanova, 1962], we observed the pest feeding on the *Thladiantha dubia* only once in our own allotment in 2023 (Figs 3–5). This can be explained by the fact that the *Thladiantha dubia* is grown in Primorsky krai predominantly as an ornamental crop, very rare in nature, and classified as an anthropophyte [Gular'yanc, 2017].

Feeding on the *Aralia elata*, the *Phellodendron amurense*, and the *Arctium lappa* led to the death of the larvae in all experimental variants (Fig. 6). The lowest mortality rate was observed when the larvae fed on potato (st) (10.3 %); the highest mortality rate was in the variants with the *Vitis amurensis* (86.5 %) and the *Crataegus maximowiczii* (72.3 %). The success level of fat accumulation on different crops was determined by measuring the changes in the larval weight and morphometric parameters of the body. Compared to the control (potato), the most beneficial food source was the *Thladiantha dubia*. The weight gain of an imago relative to the weight at the first instar was 1.73 ± 0.01 mg (Table 1).

The highest ratio of the larval body length to body width relative to the control (potato) was observed when the larvae fed on the *Thladiantha dubia* (3.18:1.062), the lowest when they fed on the *Vitis amurensis* (1.51:0.50). In general, the larvae were thin while feeding on the *Crataegus maximowiczii* and *Vitis amurensis*. The turgor pressure was low, which resulted in wrinkling.

Feeding on the studied plant species influenced the growth rate and constant as well (Table 2, Fig. 7).

The insects that fed on the *Thladiantha dubia* were characterised by the most optimal parameter values. Feeding on the *Vitis amurensis* and *Crataegus maximowiczii* decreased the growth rate and constant and increased the total duration of the ontogeny delaying the developmental stages.



Figs 3–5. Imagines of the potato ladybird beetle feed on *Thladiantha dubia*. 3 — ladybird imago and damage on goldencreeper leaves; 2 — leaf damage after ladybird imago feeding; 3 — ladybird imago on goldencreeper leaf.

Рис. 3–5. Питание имаго картофельной коровки на *Thladiantha dubia*. 3 — имаго и следы повреждений на листьях тладианты сомнительной; 4 — повреждение листа после питания коровки; 5 — имаго коровки на листе тладианты сомнительной.

Table 1. Weight of the potato ladybird beetle while feeding on different crops
Таблица 1. Вес картофельной божьей коровки при питании разными культурами

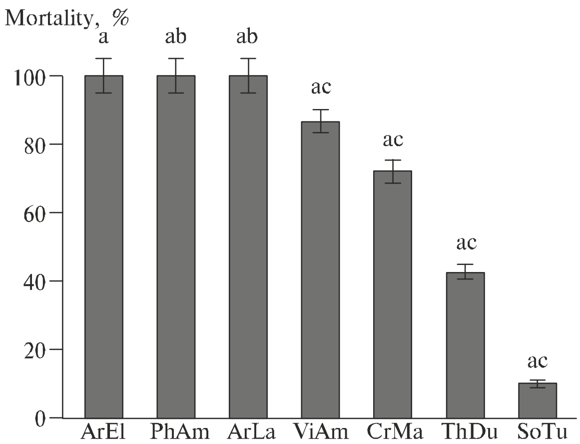
Plant species	Developmental stages weight, mg					
	Larvae, instar				Pupa	Imago
	I	II	III	IV		
Crataegus maximowiczii	5.06 ± 0.02	6.25 ± 0.02	8.25 ± 0.02	10.20 ± 0.02	10.25 ± 0.05	10.55 ± 0.05
Vitis amurensis	5.02 ± 0.01	7.25 ± 0.01	8.25 ± 0.01	9.01 ± 0.01	9.08 ± 0.05	9.25 ± 0.05
Thladiantha dubia	7.25 ± 0.02	8.04 ± 0.01	10.25 ± 0.01	12.05 ± 0.01	12.28 ± 0.05	12.54 ± 0.05
Solanum tuberosum (st)	10.25 ± 1.02	25.01 ± 1.01	30.25 ± 2.02	53.25 ± 1.25	54.38 ± 2.05	56.45 ± 2.25

Table 2 Growth rate and constant of the larvae while feeding on different crops
Таблица 2 Интенсивность и величина роста личинок при питании различными культурами

Plant species	Growth rate	Growth constant	Total time period from egg to imago, days
Thladiantha dubia	0.27 ± 0.02	3.11 ± 0.25	22.3 ± 0.75
Crataegus maximowiczii	0.08 ± 0.01	1.06 ± 0.19	32.4 ± 0.75
Vitis amurensis	0.05 ± 0.01	1.03 ± 0.10	35.5 ± 0.28
Solanum tuberosum (st)	0.32 ± 0.02	3.22 ± 0.22	21.3 ± 0.81

There are few research papers on the feeding of the potato ladybird beetle and most of them are outdated. A.N. Ivanova [Ivanova, 1962] stated that, according to her scientific observations, potato ladybird beetles could develop normally only on the *Arctium lappa* if happened to be outside an agroecosystem. However, our research discovered a 100 % mortality rate of the sample when the insects fed on the *Arctium lappa*. Naoyuki Fujiyama [Fujiyama, 2022] reports a population of *H. viginioctomaculata* that entirely depends on *Solanum megacarpum* in Yamagata, northern Honshu. The author suggests that *S. Megacarpum* was the original host plant of *H. vigintioctomaculata* on Honshu.

Adaptation to new nutrition is an ongoing process in nature. There is evidence that switching to a new fodder plant can change the food-seeking behaviour of insects sometimes. After several generations, this insect species not only adapts to the new food source but also prefers it to the original one. For example, the Colorado potato beetle, which formerly fed on wild nightshades in Colorado, switched to cultivated potato and turned into the most dangerous potato pest in the North America and Western Europe [Matsishina, 2011]. In the same way, the 24-spot ladybird *Subcoccinella vigintiquatuorpunctata* switched from wild representatives of the Chenopodioideae to the cultivated ones (beet) [Baldwin, 1990]. A well-known example of a switch to a new fodder plant is the woolly apple aphid *Eriosoma lanigerum* preferring European apple trees to the American elm. As the result, a part of the population lost its ability to use the American elm as a food source [Wearing et al., 2010]. In Primorsky krai, where lands in taiga and mountain taiga forests were reclaimed for agriculture during the Soviet times, the fauna was observed to switch to other fodder plants. Some species of the original ecosystems did not find suitable conditions for their development. Few others turned into pests of agricultural crops, e.g. the buckwheat weevil *Rhinoncus sibiricus* [Potyomkina et al., 2008]. We suggest that the original fodder plants of the potato



ArEl — *Aralia elata*, PhAm — *Phellodendron amurense*,
ArLa — *Arctium lappa*, ViAm — *Vitis amurensis*,
CrMa — *Crataegus maximowiczii*, ThDu — *Thladiantha dubia*,
SoTu — *Solanum tuberosum*.

Fig. 6. Larval mortality rateof the potato ladybird beetleafter feeding on different crops. Notes: Standard errors were estimated using the bootstrap method with a resampling of 100,000. Differences were compared using the paired bootstrap test. Values labelled with different letters indicate significant differences ($p \leq 0.01$).

Рис. 6. Смертность личинок картофельной коровки при питании различными культурами. Примечание: стандартные ошибки оценивались с помощью бутстреп-метода с повторной выборкой 100 тыс. раз. Различия сравнивались с помощью парного бутстреп-теста. Значения, обозначенные разными буквами, указывают на значительные различия между ними ($p \leq 0{,}01$).

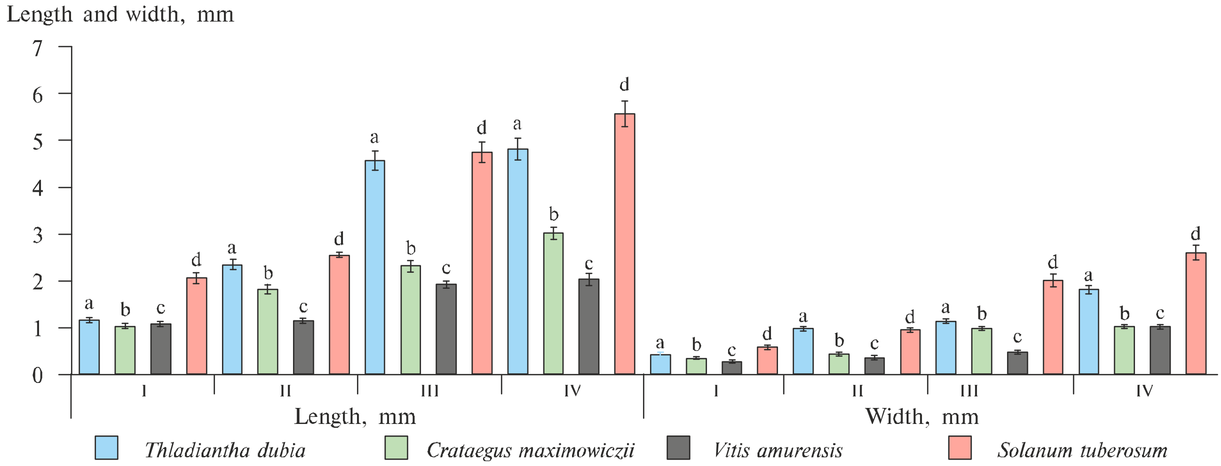


Fig. 7. Ratio of the body length(mm) to the body width of the different instar larvae after feeding on different crops. Notes: Standard errors were estimated using the bootstrap method with a resampling of 100,000 times. Differences were compared using the paired bootstrap test. Values labelled with different letters indicate significant differences ($p \leq 0.010$)

Рис. 7. Соотношение длины и ширины тела личинок (мм) разных возрастов при питании различными культурами. Примечание: стандартные ошибки оценивались с помощью бутстреп-метода с повторной выборкой 100 тыс. раз. Различия сравнивались с помощью парного бутстреп-теста. Значения, обозначенные разными буквами, указывают на значительные различия между ними ($p \leq 0{,}01$)

ladybird beetle were herbaceous plants from the families Solanaceae and Cucurbitaceae about 103 years ago. A low population density of the nightshades and cucurbits in the habitat of the potato ladybird beetle prevented the phytophage from multiplying exponentially and colonising new territories. Switching to cultivated potato proved to be beneficial for the pest and increased its survival rate and fecundity.

Conclusion

Our research results demonstrated a strong influence of the food quality on the survivability of the potato ladybird beetle. Potato proved to be the most beneficial fodder plant for the insect. Feeding on this crop led to the greatest body size of the larvae, a lower mortality rate, and the highest growth rate. The parameter values were significantly lower when the larvae fed on the *Thladiantha dubia*. However, the *Thladiantha dubia* were a more beneficial food source than the *Aralia elata*, the *Phellodendron amurense*, the *Arctium lappa*, the *Vitis amurensis*, and the *Crataegus maximowiczii*. Such difference in the influence of the fodder plants on the potato ladybird beetle might indicate a complicated pattern of transfer between fodder environments. Potato being more nutritious than wild plants is favoured by the polyphage and other fodder plants play the role of the biotopes for winter hibernation.

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