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Morphometric characteristics of juvenile growth in *Molipteryx fuliginosa* (Uhler) (Heteroptera, Coreidae) from the South of the Russian Far East

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Abstract. The paper provides original data on the duration of each instar period, growth dynamics, and morphometric characteristics of the preimaginal development up to the adult stage in *Molipteryx fuliginosa* (Uhler, 1860). The data were obtained by observations under natural and close-to-natural conditions in the South of the Russian Far East. Nymphal instars in *M. fuliginosa* have the following duration (days): 5–7 (m = 6.0 ± 0.87) (instar I); 13–16 (m = 14.5 ± 1.19) (II); 7–8 (m = m=7.5 ± 0.54) (III); 11–23 (m = 16.6 ± 3.93) (IV); and 19–38 (m = 27.9 ± 5.96) (V). With each molt, nymphs grow in size. The increases in body length and width are quite proportional at all the stages and account for 1.2–1.5 times. In instar II nymph, before the emergence of wing buds, these values are slightly higher: 1.5-fold and 1.4-fold in length and width respectively. The same is observed in instar V during the formation of sex differences: the body length increases 1.3-fold in ♂ and 1.5-fold in ♀. In the longest stage of development, the width of ♂ increases 1.2-fold, while the width of ♀ increases 1.4-fold. In middle-instar (III) nymph, the body growth rate is lower than in instar II. This period is marked by the development of the externally visible distinguishing traits of instar III nymphs — the tips of wing pads and the elytral buds. In older nymphs (stages IV and V), the duration of development extends again. The development of wing pads continues, and the sex differences are formed. The ratio of the body lengths of the nymphs relative to the adult body length (A, assumed to be 1) is as follows: I: II: III: IV: V: A = 0.2: 0.3: 0.4: 0.6: 0.8: 1. A comparative analysis of developmental patterns in the leaf-footed bug *Molipteryx fuliginosa* (Uhler, 1860) and the Far Eastern subspecies of the dock bug *Coreus marginatus orientalis* (Kiritshenko) (Heteroptera, Coreidae) in the South of Primorsky Territory has shown that the transition from nymph to imago lasts 40–45 days in *C. m. orientalis* and 55–83 days in *M. fuliginosa*. The average duration of instar I stage of the two species is similar. However, *M. fuliginosa* nymphs develop more slowly from instar II to V than *C. m. orientalis* nymphs by 4, 3, 11, and 13 days, respectively.

Keywords: Heteroptera, Coreidae, *Molipteryx fuliginosa*, immature stages, juvenile dynamics, larvae, imago, Russian Far East.

Морфометрические показатели ювенильной динамики *Molipteryx fuliginosa* (Uhler) (Heteroptera, Coreidae) на юге Дальнего Востока России

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Аннотация. Приводятся оригинальные данные продолжительности развития каждого личиночного возраста, динамики роста и морфометрических показателей преимагинальных фаз до имаго *Molipteryx fuliginosa* (Uhler 1860), полученные на основе наблюдений в естественных и приближенных к естественным условиях на юге Дальнего Востока России. Продолжительность времени развития личинок *M. fuliginosa* (дни) составляет соответственно: 5–7 (m = 6,0 ± 0,87) (возраст I); 13–16 (m = 14,5 ± 1,19) (II); 7–8 (m = 7,5 ± 0,54) (III); 11–23 (m = 16,6 ± 3,93) (IV); 19–38 (m = 27,9 ± 5,96) (V). С каждой линькой личинки увеличиваются в размерах. Интенсивность роста тела в длину и ширину на всех стадиях происходит довольно пропорционально, в 1,2–1,5 раза. У личинки II возраста перед появлением зачатков крыльев эти значения несколько выше: длина увеличивается в 1,5 раза, ширина в 1,4 раза. То же наблюдается в V возрастной стадии, при формировании половых различий: длина тела ♂ растёт в 1,3 раза, у ♀ в 1,5 раза. Ширина ♂ увеличивается в 1,2 раза, а у ♀ в 1,4 раза, при самом продолжительном сроке развития. У личинки среднего возраста (III) интенсивность роста тела ниже, чем у личинки II возраста, в этот период формируются внешне видимые отличительные признаки личинок III возраста — вершины крыловых чехликов и зачатки надкрылий. У личинок старших стадий (IV и V) продолжительность развития также увеличивается, продолжается развитие крыловых чехликов и формируются половые различия. Отношение длины тела нимф к длине тела взрослой особи (A, принятое равным 1) следующее: I: II: III: IV: V: A = 0,2: 0,3: 0,4: 0,6: 0,8: 1. Сравнительный анализ особенностей развития в условиях юга Приморского края *Molipteryx fuliginosa* (Uhler) и дальневосточного подвида щавелевого клопа — *Coreus marginatus orientalis* (Kiritshenko) (Heteroptera, Coreidae) показал, что развитие личинок *C. m. orientalis* до имаго укладывается в 40–45 дней, *M. fuliginosa* — в 55–83 дня. При этом средние показатели продолжительности развития I стадии сравниваемых видов совпадают. Личинки от второй до пятой стадии *M. fuliginosa* развиваются медленнее, чем *C. m. orientalis* — на 4, 3, 11 и 13 дней соответственно.

Ключевые слова: Heteroptera, Coreidae, *Molipteryx fuliginosa*, преимагинальные стадии, ювенильная динамика, личинки, имаго, Дальний Восток России.

Introduction

Leaf-footed bugs (Coreidae) are phytophages, of which some are known as significant agricultural pests (Puchkov 1972, etc.). *Molipteryx fuliginosa* (Uhler 1860) is one of the four species of the genus *Molipteryx* (Kiritishenko, 1916) from the family Coreidae distributed in the southeastern Palearctic and the Oriental region (Aukema, Rieger 2006; Aukema et al. 2013). It is relatively new to the fauna of Russia, being the only representative of its genus recorded from here. To date, data on the distribution of *M. fuliginosa* in the Russian Far East have been summarized, its biotopic distribution has been described, and preliminary information on feeding in the South of Primorsky Territory has been

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provided (Kerzhner, Kanyukova 1998; Kanyukova, Vinokurov 2009; Vinokurov et al. 2010; Kanyukova 2012; Kanyukova, Ostapenko 2013; Markova, Maslov, Repsh, Ogorodnikov 2016; Markova, Maslov, Repsh 2016; Aistova et al. 2019; Markova et al. 2019; Markova, Maslov 2020).

The developmental cycle of *M. fuliginosa* was studied for one season under laboratory conditions in South Korea (Park 1996). This squash bug was found to have one generation per year, from early May to late September, and an overwinter period in the imago stage. However, there is a lack of information in the literature about the morphometric characteristics of its preimaginal stages and the dynamics of body size growth during development. No studies on morphometry of other species of this genus commonly distributed in the eastern Palearctic have been carried out before.

We have studied the morphology of preimaginal stages, published the descriptions of eggs and five nymphal instars, described the reproductive behavior of imago, the female behavior and oviposition stages of *M. fuliginosa* in Primorsky Territory (Markova, Kanyukova et al. 2017; Markova, Maslov et al. 2017).

The goal of the present study is to assess the duration of each nymphal instar and variations in proportions and rates of body growth in length and width during the preimaginal stages in *M. fuliginosa* under natural conditions in the South of the Russian Far East.

Material and methods

The material for the work was the authors' own collections made in the Ussuriysky Urban Settlement and Chuguyevsky District, Primorsky Territory, from April to October in 2015–2020. Simultaneous observations were conducted in natural habitats; in parallel, some of the bugs were kept in stationary and portable cages under the conditions close to natural (Markova, Kanyukova et al. 2017; Markova, Maslov et al. 2017; Markova et al. 2018) (Fig. 1). The studies started with the emergence of overwintered imagoes in spring and the onset of oviposition, after which the imagoes were removed. The eggs were left in the stationary cages until instar I nymphs hatched and the subsequent stages were observed until molting to imago.

Imagoes were also reared from instar III–IV nymphs collected in the wild. We examined more than 50 specimens to assess the duration of each instar development.

We measured the growth dynamics in instar I–V nymphs by their sequential measurements with an interval of 1–4 days. To do this, live nymphs were placed on a sheet of 1 mm grid paper, oriented along the grid lines, and photographed. The images were processed in the FastStone Image Viewer. The following size parameters were measured: the length and width of the body and the head capsule with eyes. The measurement date and the timing of development of each nymphal instar were recorded. To provide higher accuracy of data, specimens that had been euthanized shortly before and had not yet lost their shape and color were measured simultaneously. The body length was measured in a natural position, without compression along the body midline, from clypeus to the abdomen tip. The body width was measured at the level of abdomen, in its widest part. Some specimens were fixed in 75% alcohol for further study, but most of the hatched nymphs were placed in cages where they continued their development. The number of measured specimens for each stage was more than 20; deformed specimens were not considered. In total, we measured more than 50 imagoes, both reared and collected in the wild.

The body length of nymphs of any species may somewhat vary within the same stage, depending on body condition and proximity to molting to the next stage (Puchkov, Puchkova 1956). The body width also varies greatly. To obtain more accurate data, we made three measurements of each specimen during their development and calculated mean values. The following abbreviations are used in the report: (m±) mean value and mean squared deviation; (n) number of measured specimens; (I–V) instar I–V nymphs; ♂ male; ♀ female.

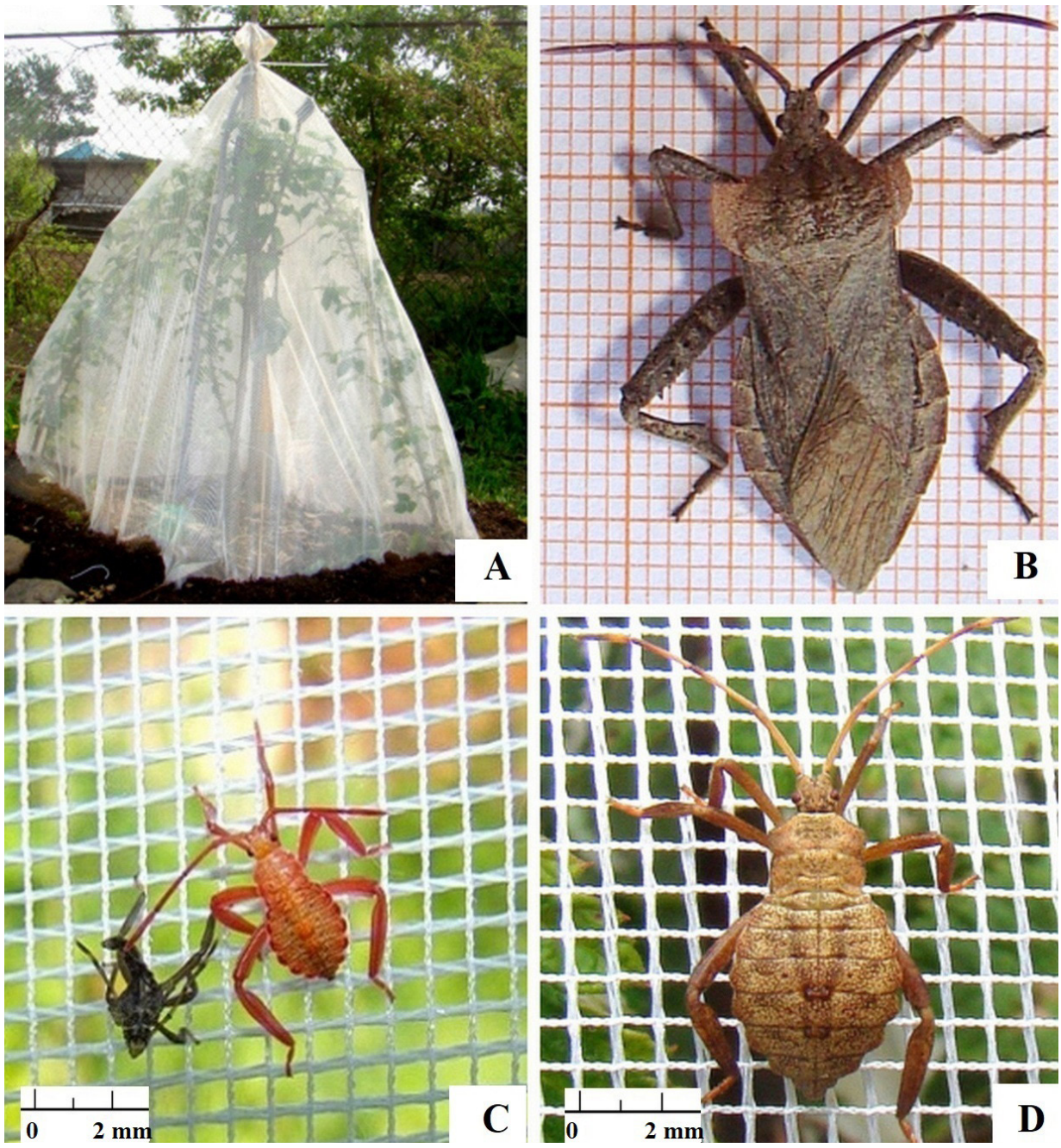

Fig. 1. *A* — a mesh netting covering a raspberry bush (*Rubus idaeus* L.) with nymphs of the squash bug *Molipteryx fuliginosa*; *B* — imago of *M. fuliginosa*; *C* — nymphal molt in *M. fuliginosa*: instar II nymph emerging from the exuviae; *D* — *M. fuliginosa* instar III nymph (photos by M. V. Maslov)

Рис. 1. *A* — садок, покрывающий целые кусты малины (*Rubus idaeus* L.) с личинками клопа *Molipteryx fuliginosa*; *B* — имаго *M. fuliginosa*; *C* — линька личинки *M. fuliginosa*: высвобождение личинки II возраста от экзувия; *D* — личинка *M. fuliginosa* III возраста (фото М. В. Маслов)

The growth dynamics of instar I–V nymphs is shown in Fig. 2. Morphometric parameters of *M. fuliginosa* nymphs and imagoes are provided in Table 1.

Results and discussion

After hatching from eggs, *M. fuliginosa* passes through five nymphal instars in their development, with their total duration coinciding in time with the summer months (Markova, Kanyukova 2017). The development of instar I nymph in cage lasts from 5 to 7 days, with an average of 6 days (n = 50). In this period of time, the nymph body length and width increase on average 1.2-fold. The growth rate of instar I nymph in length is

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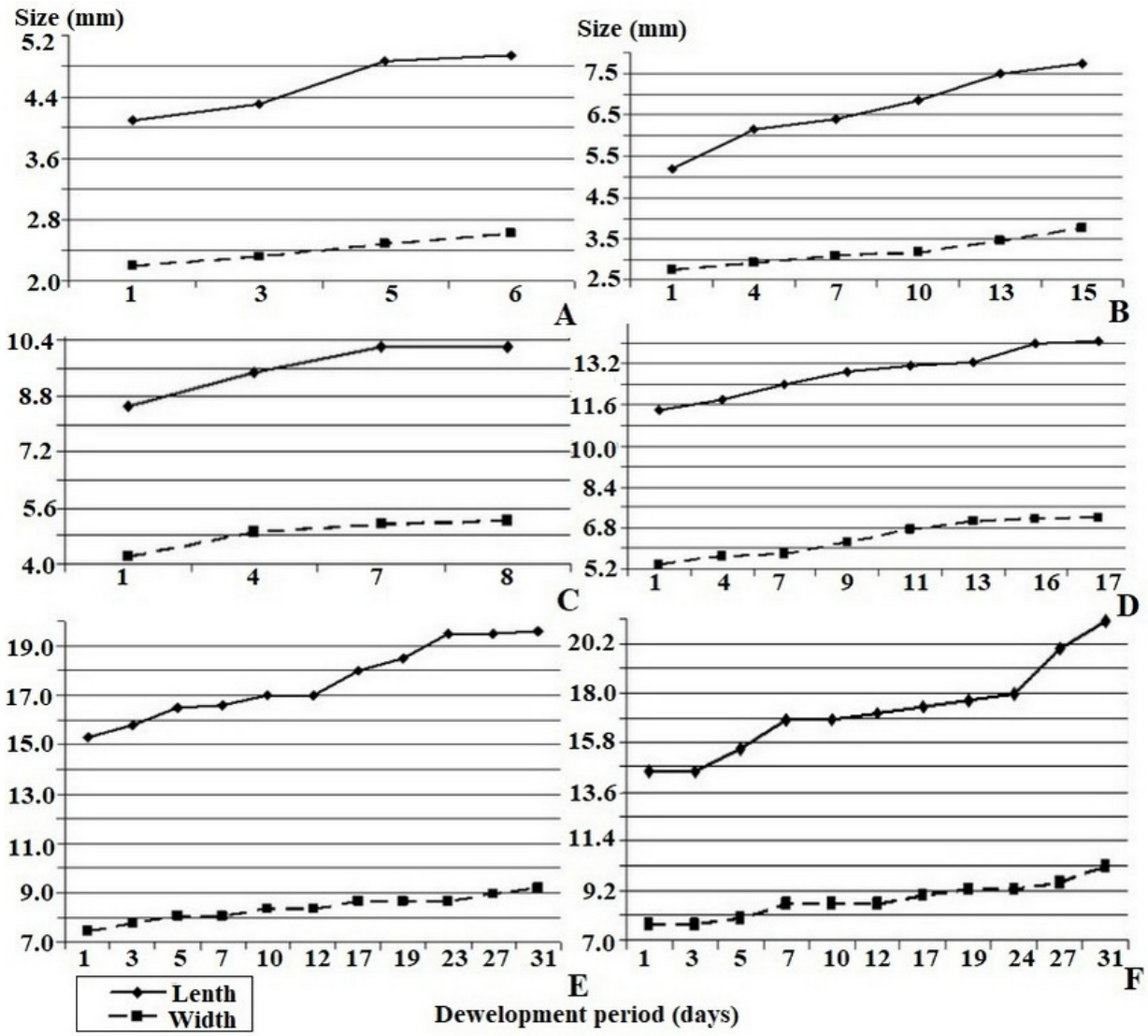

Fig. 2. Growth dynamics of *M. fuliginosa* nymphs (mean length; width at abdomen level, mm). *A* — in instar I from June 16 to July 1, 2015; *B* — in instar II from June 23 to July 16, 2015; *C* — in instar III from July 10 to July 25, 2015; *D* — in instar IV from July 19 to August 12, 2015; *E* — in instar V (♂) from August 4 to September 10, 2015; *F* — in instar V (♀) from August 4 to September 10, 2015.

Рис. 2. Динамика роста личинок *M. fuliginosa* (средняя длина; ширина на уровне брюшка, мм). *A* — Л I в период 16.06.2015—01.07.2015; *B* — Л II в период 23.06.2015—16.07.2015; *C* — Л III в период 10.07.2015—25.07.2015; *D* — Л IV в период 19.07.2015—12.08.2015; *E* — Л V (♂) в период 04.08.2015—10.09.2015; *F* — Л V (♀) в период 04.08.2015—10.09.2015

most pronounced from day 3 to 5; the abdomen width increases more evenly throughout this period (Fig. 2A). The head length and width are equal at this stage (Table 1).

During the molt and transition from instar I to II, the body length increases by 0.3 ±0.05 mm and the abdomen width by 0.1 ± 0.05 mm (n = 20) (Figs. 2A–B). The development in instar II lasts from 13 to 16 days, with an average of 14.5 days (n = 50). In this time interval, the body length increases 1.5-fold, with the growth rate being more uniform throughout this period (Fig. 2B). The abdomen width increases 1.4-fold; in the first 10 days, the growth rate is lower than in the following days. The head length to width ratio at this stage is 1:1.3 (Table 1).

In nymph molting from instar II to III, the body length increases by 0.8 ± 0.05 mm, the abdomen width by 0.4 ± 0.07 mm (n = 20) (Figs. 2B–C). The development in instar III lasts from 7 to 8 days, with an average of 7.5 days (n = 50). The body length and width grow almost synchronously. The body length in-

Table 1

Morphometric characteristics of nymphs and imago of *Molipteryx fuliginosa*

Таблица 1

Морфометрические показатели личинок и имаго *Molipteryx fuliginosa*

Instar	Size, mm			
	Body		Head	
	Length	Width	Length	Width
I (n = 50)	4.0–5.1 m = 4.5 ± 0.44	2.0–2.7 m = 2.4 ± 0.24	1.0–1.1 m = 1.0 ± 0.05	1.0–1.1 m = 1.0 ± 0.04
II (n = 50)	5.0–7.9 m = 6.5 ± 1.31	2.6–3.8 m = 3.3 ± 0.52	1.0–1.2 m = 1.0 ± 0.07	1.2–1.4 m = 1.3 ± 0.06
III (n = 50)	8.3–10.3 m = 9.4 ± 0.89	4.0–5.3 m = 4.7 ± 0.54	1.4–1.6 m = 1.5 ± 0,07	1.4–1.6 m = 1.5 ± 0.07
IV (n = 50)	11.3–14.2 m = 12.7 ± 1.37	5.2–7.3 m = 6.3 ± 0.93	1.5–1.6 m = 1.5 ± 0.05	1.9–2.1 m = 2.0 ± 0.08
V ♂ (n = 25)	♂ 15.2–21.0 m = 17.4 ± 2.23	♂ 7.4–9.5 m = 8.3 ± 0.91	♂1.9–2.1 m = 2.0 ± 0.06	♂2.1–2.4 m = 2.3 ± 0.09
♀ (n = 25)	♀ 14.4–22.0 m = 17.9 ± 3.5	♀ 7.5–11.0 m = 8.9 ± 1.4	♀ 1.8–1.9 m = 1.8 ± 0.05	♀ 2.4–2.5 m = 2.5 ± 0.05
Imago ♂ (n = 25)	♂ 20.0–25.0 m = 21.6 ± 1.19	♂ 9.1–11.0 m = 9.5 ± 0.55	♂ 2.0–2.1 m = 2.1 ± 0.05	♂ 2.7–2.9 m = 2.8 ± 0.09
♀ (n = 25)	♀ 23.0–25.0 m = 23.6 ± 0.76	♀ 11.0–13.0 m = 11.8 ± 0.69	♀ 1.8–1.9 m = 1.9 ± 0.05	♀ 2.6–2.8 m = 2.7 ± 0.07

creases 1.2-fold; the growth rate is high within the first 7 days, and subsequently stabilizes (Fig. 2C). The abdomen width increases 1.3-fold; the rate of width increase is high within the first 7 days. The head length and width at this stage are again equal (Table 1). Instar III nymph acquires a trait that distinguishes it from the two younger stages: the distinct elytral buds appear on the sides of the posterior edge of mesonotum.

In nymph molting from instar III to IV, the body length increases by 0.2 ± 0.05 mm (n = 20) (Figs. 2C–D). The development in instar IV lasts from 11 to 23 days, with an average of 16.6 days (n = 50). The increases in length and width show high rates throughout this period and occur almost synchronously (Fig. 2D). The body length increases 1.2-fold; the abdomen width, 1.3-fold. The head length to width ratio at this stage is 1.5:2 (Table 1). The tips of the elytral buds in instar IV extend beyond the middle of tergite II and cover most of the wing pads.

In nymph molting from instar IV to V, sexual dimorphism becomes pronounced. In males, the body length increases by 1.2 ± 0.05 mm; the abdomen width, by 0.3 ± 0.04 mm (Figs. 2D–E). In females, the body length increases by 0.5 ± 0.05 mm; the abdomen width, by 0.4 ± 0.04 mm (n = 20) (Figs. 2D, F). The development in instar V is the longest, lasting from 19 to 38, on average 27.9 days (n = 50). The increases in body length and width are almost synchronous. In males, the body length increases 1.3-fold, with the growth rate being highest from day 1 to 5 and from day 12 to 24. The abdomen width in males increases 1.2-fold, with the growth rate being relatively uniform throughout this period (Fig. 2E). Females grow more intensively; their body length increases 1.5-fold; the growth rate is higher from day 3 to 7 and from day 24 to 31 (Fig. 2F). The increase in the abdomen width of females is also more intensive, 1.4-fold, and becomes more pronounced from day 3 to 7 and from day 24 to 31. The head length to

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width ratio in instar V is 2:2.3; the head width grows faster than length by the end of development (Table 1). The elytral buds in instar V completely cover the wing pads, their tips extending beyond the middle of tergite III.

In male nymphs molting from instar V to imago, the body length increases by 1.8 ± 0.49 mm; the abdomen width, by 0.3 ± 0.19 mm (n=20). In females, the body length increases by 2.0 ± 0.62 mm; the abdomen width, by 1.1 ± 0.2 mm (n = 20).

Thus, the body length of the imagoes reared in cages was 21.4 ± 0.93 mm (♂) (n = 20) and 23.3 ± 0.44 mm (♀) (n = 20). In the imagoes collected in the wild, the body length was greater in some cases and reached 25 mm (♂♀) (Table 1). The body width of the imagoes grown in cages was 9.5 ± 0.26 mm (♂) (n = 20) and 11.4 ± 0.49 mm (♀) (n = 20). In the imagoes collected in the wild, the body width was also greater and reached 11.0 mm (♂) and 13.0 mm (♀) (Table 1).

In general, the ratio of the body lengths of the nymphs relative to the adult body length (A, assumed to be 1) is as follows: I: II: III: IV: V: A = 0.2: 0.3: 0.4: 0.6: 0.8: 1 (n = 300). This data agrees with Putshkov's conclusions about the nymph to imago body length ratios in bugs of the family Lygaeidae (Putshkov 1958).

The head length and width of nymph are the most conservative parameters (Putshkov, Putshkova 1956). After shedding nymphal skin at any instar stage, nymph has a head of constant size which does not vary during the subsequent development throughout this stage. Our data has shown that the head length and width are equal in early-instar nymphs of *M. fuliginosa*, whereas in the older stages the head width increases faster than its length by the end of the stage development.

With each molt, nymphs grow in size. The increase in body length and width at all stages is quite proportional, 1.2–1.5-fold. In instar II, before the emergence of wing buds, these values are slightly higher: the length increases 1.5-fold and the width 1.4-fold. The duration period of instar II is also extended. The same is observed in instar V nymphs as sex differences are formed: the body length increases 1.3-fold in ♂ and 1.5-fold in ♀. The width increases 1.2-fold in ♂ and 1.4-fold in ♀ during the longest development period.

In middle-instar (III) nymphs, the body growth rate is lower than in instar II. This period is marked by the development of the externally visible distinguishing traits of instar III nymphs—the tips of wing pads and the elytral buds. In older instars (IV and V), the development period is also extended, the wing pads continue growing, and sex differences are formed.

It has been found that the imago's body length varies from 23 to 23 mm (♂) and from 23 to 24 mm (♀). The body length of the large imagoes collected in the wild, in some cases, reached 25 mm (♂♀). The width at the abdomen level varies from 9.1 to 10.0 mm (♂) and from 11.0 to 12.0 mm (♀). The maximum body width of large imagoes collected in the wild, in rare cases, reached 11.0 mm (♂) and 13.0 mm (in ♂♀).

The duration of development of *M. fuliginosa* nymphs increases by a certain number of days with each stage: 5–7 (m = 6.0 ± 0.87) (I); 13–16 (m = 14.5 ± 1.19) (II); 7–8 (m = 7.5 ± 0.54) (III); 11–23 (m = 16.6 ± 3.93) (IV); 19–38 (m = 27.9 ± 5.96) (V).

Earlier, we presented the developmental patterns of the Far Eastern subspecies of the *Coreus marginatus orientalis* (Kiritshenko, 1916) (Heteroptera, Coreidae) in the South of Primorsky Territory. It was found that the embryonic period in the species lasts, on average, 11 days. The nymphal development has generally the following pattern: instar I, 6 days; instar II, 10–11 days; instar III, 5 days, instar IV, 6 days; and instar V, 13–16 days (m = 15 days). The transition from nymph to imago takes 40–45 days (Markova et al., 2020)

In *M. fuliginosa*, the nymph to imago transition lasts 55–83 days. The average durations of the instar I development in the species under study are similar. However, *M. fuliginosa* nymphs develop more slowly from instar II to V than *C. m. orientalis* nymphs by 4, 3, 11, and 13 days, respectively.

The obtained results have a theoretical and practical value. Thus, the study contri-

butes to the biology of species of the genus and the entire family Coreidae. Moreover, the study outcomes may find practical application in the development of plant protection measures.

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