ISSN 0013-8738, Entomological Review, 2023, Vol. 103, No. 1, pp. 21–32. © Pleiades Publishing, Inc., 2023.
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Biological Features of *Urostylis annulicornis* Scott (Heteroptera, Urostylididae) in the South of the Russian Far East

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Received November 5, 2022; revised January 30, 2023; accepted January 30, 2023

Abstract—Nymphal and adult *Urostylis annulicornis* Scott, 1874 were reared in cages from eggs overwintered under oak bark in the south of Primorskii Territory of Russia. The nymphs hatch before the onset of oak vegetation season and develop under the bark, consuming the jelly-like coating of the egg mass. As the oak leaves unfold, the II–III instar nymphs leave their shelters and begin feeding on leaf sap. Adults live in the oak crown. The sequence of molts of all the nymphal instars, their feeding, and the timing of seasonal development of the species in nature are described.

Keywords: true bugs, Heteroptera, Urostylididae, *Urostylis annulicornis*, ootheca, overwintering, nymphs, seasonal development, phenology, Primorskii Territory, *Quercus mongolica*

DOI: 10.1134/S0013873823010049

The family Urostylididae belongs to the superfamily Pentatomoidea of the infraorder Pentatomomorpha and includes 8 genera and over 170 species (Rider et al., 2018). Species of this family are distributed in the Eastern Hemisphere from the Indo-Malayan (Oriental) Region to the southeastern periphery of the Palaearctic, with more than 80 species known in the Palaearctic Region (Rider, 2006). In East Asia, they occur in most of China, Korea, and Japan. The Chinese entomologists have published reviews of the Urostylididae fauna (Yang, 1939; Hsiao et al., 1977) and described new species from China, including Taiwan (Ren, 1984a, 1984b, 1997, 2004; Ren and Lin, 2003, etc.). The Indian fauna of the family has been studied by I. Ahmad and co-authors (Ahmad et al., 1992). No modern revision of Urostylididae has been published; its taxonomic position within the superfamily Pentatomoidea has been repeatedly discussed in the literature, and now this primitive family is considered a sister group of all the other Pentatomoidea (Grazia et al., 2008).

Seven species of Urostylididae are present in the south of the Russian Far East. They belong to 2 genera: *Urochela* Dallas, 1850 with 2 species *U.* (*Chlorochela*) *flavoannulata* (Stål, 1854) and *U.* (*U.*) *quadrinotata* (Reuter, 1881), and *Urostylis* Westwood, 1837 with 5 species: *U. annulicornis* Scott, 1874, *U. lateralis* Walker, 1867, *U. linguiformis* Ren, 1984, *U. striicornis* Scott, 1874, and *U. trullata* Kerzhner, 1966 (Kanyukova, 1988, 2010). The species distributed in Russia vary in body size from 7.7 to 17 mm. Bugs of this family have a flattened body and more weakly sclerotized hemelytra as compared with other Pentatomoidea. Their dorsal coloration is predominantly green or yellow-green, except for the brownish-red hemelytra in *Urochela quadrinotata*.

The family was earlier known as Urostylidae (Kerzhner, 1966, 1988; Kerzhner and Petrova, 1975; Kanyukova, 1988, 2010, etc.), but now the corrected spelling Urostylididae is used (Berger et al., 2001). Kerzhner (1966) published a revision of the fauna of this family in

the former USSR territory, a key to 2 genera and 5 species known at that time, a description of the subgenus *Chlorochela* with an overview of its constituent species from South China, and a description of the new species *Urostylis trullata*. Two species new to the Russian fauna were subsequently recorded for Primorskii Territory: *Urostylis striicornis*, attracted to the light of a tubular quartz mercury lamp (Kerzhner and Petrova, 1975), and *U. linguiformis* (Kerzhner, 1988).

Bugs of the family Urostylididae are herbivorous, but host plants are known for only a few species (Rider, 2006, 2022; Rider et al., 2018). Species of the genus *Urostylis* are associated with oaks *Quercus* L. (Maa, 1947; Kobayashi, 1953, 1965; Kerzhner, 1966; Schaefer and Ahmad, 1987). In particular, T. Kobayashi recorded different oak species as host plants for *Urostylis striicornis* and *U. westwoodi*. Members of this genus were collected on oaks and other plants in the Russian Far East. For instance, *U. annulicornis* was recorded by I.M. Kerzhner on the Mongolian oak *Q. mongolica* Fisch. ex Ledeb., while single specimens were also collected by him from the walnut tree *Juglans* sp. and the willow *Salix* sp.; the oak was recorded as the host plant for *U. lateralis* (Kerzhner, 1966). Based on the results of field studies in Primorskii Territory in 1982, I.M. Kerzhner concluded that *U. annulicornis* and *U. trullata* were associated with *Q. mongolica*, while *U. lateralis* and *U. striicornis* could be found on *Q. mongolica* and *Q. dentana*. At the same time, *U. linguiformis* was found only on *Q. dentana* in the south of Primorskii Territory (Kanyukova, 1988). In his list of insects of the Sikhote-Alin Nature Reserve, Kuznetsov (2000) also recorded *U. annulicornis* and *U. trullata* (the material was identified by the first author) from the Mongolian oak and mentioned that these species had been found on other broadleaf trees as well. He also reported an outbreak of *U. annulicornis* in the reserve in 1998, resulting in severe damage to oak leaves; however, it is possible that damage was caused by both *Urostylis* species (V.N. Kuznetsov, pers. comm.).

Plants of the family Rosaceae have been also recorded as hosts of *Urochela* bugs. *Urochela luteovaria* Distant is known in Japan as a pest of fruit and ornamental woody plants, forming outbreaks on the apple trees *Malus* sp., pears *Pyrus* sp., plum and cherry trees *Prunus* sp., and other cultivars; the bugs suck cell sap from shoots, less often from fruits (Kobayashi, 1965). In the territory of Russia, *U.* (*Ch.*) *flavoannulata* was found by Kulik (1965) in Transbaikalia on the bird cherry *Padus* sp., apple trees, and willows *Salix* sp.; according to Kerzhner (1966), this bug species occurred on the bird cherry and the wild apple tree *Malus* sp. Rosaceae were listed as host plants of *U. quadrinotata* by Kulik (1965), but nymphs and adults of this species were collected on *Ulmus* sp. in Korea (Josifov and Kerzhner, 1978).

The biology of Urostylididae was studied on the Japanese island of Shikoku by Kobayashi (1953, 1965), who kept the bugs in Petri dishes in the laboratory and was able to obtain the nymphs. He described the shape of the eggs and oothecae (egg clutches), published diagnoses of the nymphs of *Urostylis striicornis*, *U. westwoodi*, and *Urochela luteovaria*, and characterized the life cycle of these species as univoltine (Kobayashi, 1965). The two genera were shown to have different shapes of the oothecae, covered with a jelly-like substance in both genera. The role and composition of this substance were studied in two *Urostylis* species in Tsukuba (Kaiwa et al., 2014). Apart from protecting the eggs from mechanical damage and microorganisms, the gelatinous coating of the ootheca serves as a nutrient reserve rich in polysaccharides and contains symbiotic bacteria that are passed on to the nymphs.

According to the data of Kobayashi (1965), species of the genus *Urochela* have lumpy oothecae positioned vertically on the bark underside or on the leaves of the host plant. The nymphs hatch in September, during the decline of vegetation. They feed on the gelatinous substance of the ootheca, molt to the II instar, and move into bark fissures for hibernation. The overwintered nymphs move in spring onto the buds or new shoots of the host plant. Adults were recorded since the end of June, and oviposition was observed in September (Kobayashi, 1965).

Species of the genus *Urostylis* have elongated, strap-shaped oothecae positioned on the bark of the host plant. They overwinter at the egg stage; the nymphs hatch in early February, suck the gelatinous substance of the ootheca, molt to the II instar, and move onto the emerging buds and shoots of the host plant, where they start feeding on sap. Adults were recorded from the middle to the end of May, and oviposition was observed from the middle to the end of November (Kobayashi, 1965).

The II instar nymphs of *Urochela* (*Ch.*) *flavoannulata* overwinter in the detritus in willow and bird cherry

Fig. 1. Observations of the development of *Urostylis annulicornis* Scott on the Mongolian oak *Quercus mongolica* Fisch. ex Ledeb.: (*1*) ootheca on the bark underside; (*2*) a bark fragment with an ootheca on the underside, taped to the oak trunk for observations under natural conditions; (*3*) the II instar nymphs moving onto young leaves for feeding; (*4*) a stationary cage enclosing a young oak plant under natural conditions.

shrubs along the river banks in Transbaikalia (Kulik, 1965). At the same time, overwintering at the adult stage was mentioned in the review of Urostylididae of the USSR fauna (Kerzhner, 1966) and in the publication devoted to new species records (Kerzhner and Petrova, 1975). Hibernating adults of *Urochela quadrinotata* were found by Kuznetsov (1977) in rock cracks in Primorskii Territory. The biology of *Urostylis* species in the south of the Russian Far East has been so far unknown. This paper reports the results of studying the developmental phenology of *Urostylis annulicornis* nymphs hatched from an overwintered egg clutch.

MATERIALS AND METHODS

The research was carried out in the forest biotopes of the Ussuriysk Urban District from April to October 2022. Mongolian oak trees were examined to assess their infestation, the plants were surveyed along a route, and the egg clutches of bugs were described, sampled, and documented with photos. The total surveyed area was about 6 ha. The egg clutches found on seven examined trees were left for further observation under the corky outer bark (rhytidome) fixed on the trunk with adhesive tape. Some egg clutches were sampled together

with the bark fragments and kept in portable cages under natural conditions until hatching of the nymphs. The proper humidity level in the cages was maintained using moistened moss clumps. The II and III instar nymphs on the bark fragments containing the remainder of the egg clutches were transferred to stationary cages (Markova et al., 2018) installed around oak seedlings (Fig. 1, *4*) and kept there until the final molt to adults. The nymphs were photographed and measured, and their development and molting was continuously monitored. All the field and laboratory studies were carried out by T.O. Markova and M.V. Maslov.

In addition to our samples, we studied the collection material of the Zoological Institute of the Russian Academy of Sciences (St. Petersburg, Russia; ZIN) and the Zoological Museum of the Far Eastern Federal University (Vladivostok; FEFU). For comparison, we also used the photos of oothecae and nymphs of *Urostylis* sp. made by the late Yu.A. Semeikin in 2015 and 2016 near Akademgorodok and the Botanical Garden of Vladivostok.

RESULTS

Urostylis annulicornis Scott, 1874

Material. Russia. *Primorskii Territory*, Ussuriysk Urban District, env. of Kaimanovka (43°37′49″N, 132°13′49″E), buffer zone of the Leopard Land National Park, oak-cedar pine forest, 8 clutches collected on 8–10.IV.2022, adults (4 ♂, 5 ♀) emerged on 16–25.VI.2022.

Distribution. South of the Russian Far East: Jewish Autonomous Region, south of Khabarovsk and Primorskii territories, Kunashir Island; Northeast China, Korea, Japan.

Habitats. Egg clutches were collected on a floodplain terrace in an oak-cedar pine forest with Manchurian fir, shrubs, and motley grass. The tree stand is composed of Korean pine *Pinus koraiensis* Siebold et Zucc., Mongolian oak, Manchurian fir *Abies holophylla* Maxim., and painted maple *Acer mono* Maxim., with admixture of Manchurian ash *Fraxinus mandshurica* Rupr., castor aralia *Kalopanax septemlobus* (Thunb.) Koidz., tigernut *Juglans mandshurica* Maxim., Manchurian striped maple *Acer tegmentosum* Maxim., heartleaf hornbeam *Carpinus cordata* Blume, and Asian white birch *Betula platyphylla* Sukacz. The shrub layer has no apparent dominants and is composed of hazel *Corylus mandshurica* Maxim., spindle *Euonymus pauciflora* Maxim., Manchurian viburnum *Viburnum burejaeticum* Regel et Herd., Siberian ginseng *Eleutherococcus senticosus* (Rupr. et Maxim.) Maxim., and mock orange *Philadelphus tenuifolius* Rupr. et Maxim. There are the woody vines *Actinidia arguta* (Siebold et Zucc.) Planch. ex Miq. and *A. kolomikta* (Maxim. et Rupr.) Maxim.

Life cycle. The egg clutches (oothecae) were found on 8–10.IV.2022 on the underside of the Mongolian oak bark. The diameter of the examined trunks ranged from 19 to 70 cm (m[1] = 40 cm), the bark thickness above the clutch, from 0.3 to 0.7 cm (m = 0.5 cm). The clutches were located from 80 to 166 cm (m = 117.3) above the ground, and the neighboring trees with clutches were from 0.2 to 250 m apart (m = 81.8). Most of the clutches were located in the south-facing parts of the trunks (Table 1).

The oothecae were elongated, allantoid, from 7.5 to 16 mm long (m = 8.8); those with a single row of eggs were from 2.5 to 3 mm wide (m = 2.2), and those with 2 or 3 rows of eggs were from 5.4 to 7 mm wide (m = 6.2). The eggs formed from 2 to 4 layers in the ootheca. The entire clutch was evenly covered with a dense, gelatinous olive-colored coating (Fig. 1, *1*; Fig. 2, *1*, *2*). The number of eggs in a clutch varied from 26 to 109 (m = 50).

The newly hatched I instar nymphs were recorded since the end of the first 10 days of April, when the development of oak leaves had not yet begun (Table 2). The I instar nymphs had an oval, dorsally convex body 1.2–1.5 mm long. The nymphal coloration developed according to the pattern described for Pentatomoidea by Putshkov and Putshkova (1956): first the body was green, then dark spots appeared on the head, on the sides of the thorax except for its midline, and on three abdominal tergites; the overall abdominal coloration was pale, greenish-brown. The nymphs stayed motionless in the egg mass and sucked the gelatinous substance of the ootheca (see Fig. 2, *2*). The duration of the I instar varied from 12 to 14 days (m = 13).

[1] m is the mean value.

Table 1. Location and characteristics of the studied egg clutches of *Urostylis annulicornis* Scott

No.	Collection date	Diameter of oak trunk, cm	Thickness of bark over clutch, cm	Position of clutch above ground, cm and its orientation on the trunk	Length × thickness of clutch, mm	Number of eggs	Mean distance between trees with clutches, m
1	8.IV.22	70	0.5	130, northeast facing	9 × 2.7	26	49
2	9.IV.22	25	0.7	166, south facing	16 × 1.8 8 × 1.8 8.8 × 1.8	52 29 21	189.6
3	9.IV.22	62	0.3	95, south facing	7.5 × 2.5	32	51
4	9.IV.22	47	0.7	107, northwest facing	8 × 3	49	15.5
5	9.IV.22	19	0.3	108, south facing	9 × 2.5	30	65.6
6	9.IV.22	34	–	132, south facing	–	–	122.5
7	10.IV.22	40	0.7	80, north facing	16 × 3.5 12 × 3.5	48 61	175.5
8	10.IV.22	23	0.4	120, southwest facing	10 × 3	33	175.0

Dash indicates the absence of data (the clutch was located in bark fissure); one tree had a forked trunk.

Table 2. Phenology of *Urostylis annulicornis* Scott under natural conditions and in stationary cages in Primorskii Territory of Russia, by months and 10-day intervals: data of 2022

Stage	April			May			June			July			August			September		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Egg	+	+	+															
I instar	+	+	+															
II instar			+	+	+													
III instar				+	+	+												
IV instar					+	+	+											
V instar						+	+	+										
Adult								+	+	+	+	+	+	+	+	+	+	+

The II instar nymphs appeared at the beginning of the last third of April. They had an oval, but more elongate body 1.8–2.2 mm in length. Their abdominal coloration changed from grayish-brown to reddish (see Fig. 2, *3*). Since the end of April, the nymphs left the clutches and dispersed under the bark in groups of 6–8 individuals. The remaining nymphs continued to feed on the gelatinous coating of the ootheca; when kept in a cage, they sometimes also consumed the coating of another clutch located nearby and containing the remains of dead eggs or undeveloped nymphs. Feeding on the unfolding oak leaves was recorded since May 1–3, but no feeding on the buds was observed. The duration of the II instar varied from 9 to 12 days (m = 10.5).

The III instar nymphs were recorded from the end of April to the beginning of May. They had a body length of 3.0–3.5 mm. Mass molting was observed on May 3, 2022. The abdominal coloration in most nymphs changed from reddish to grayish-yellow with a pinkish-red tint

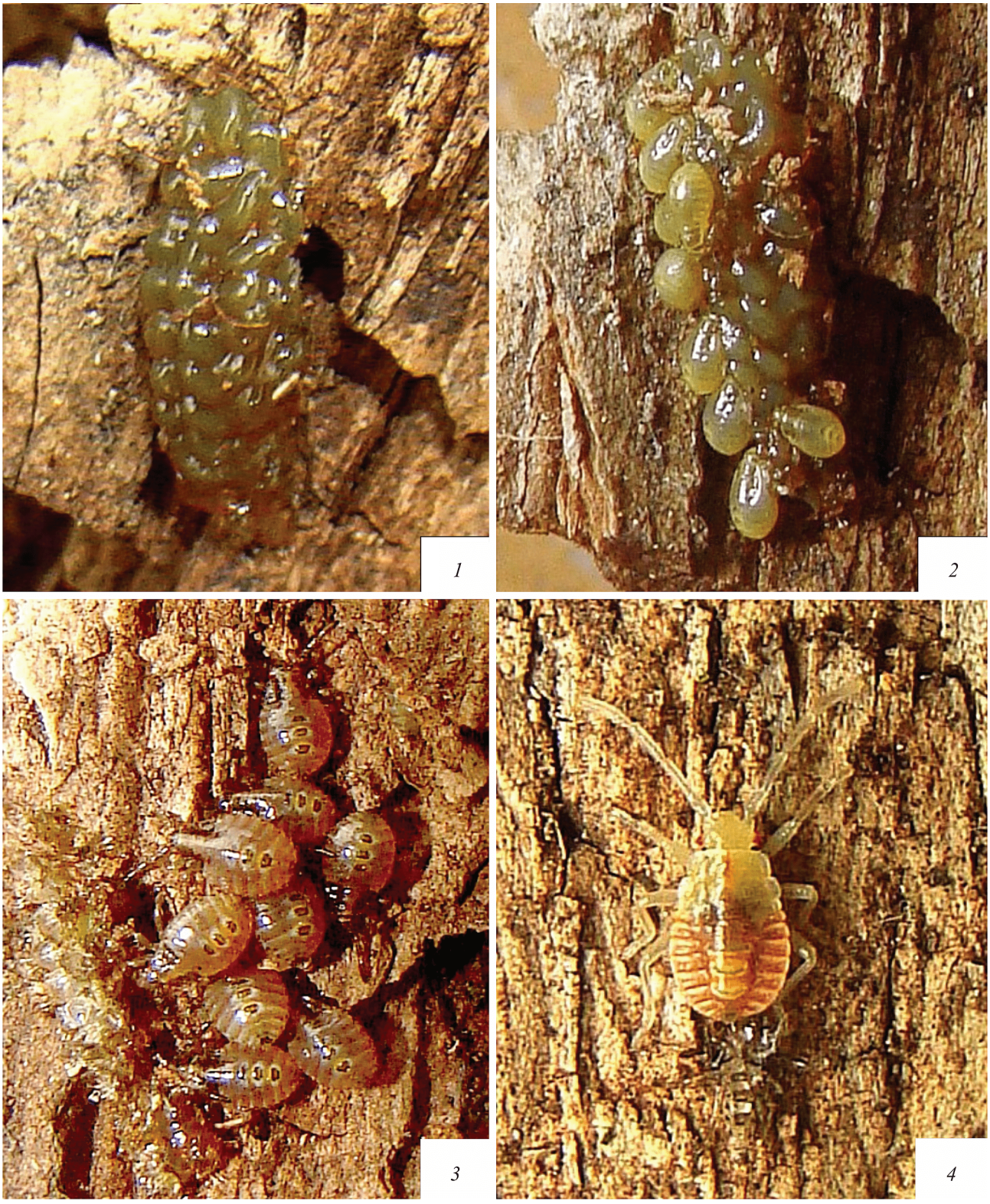

Fig. 2. Stationary observations of the development of an egg clutch of *Urostylis annulicornis* Scott on *Quercus mongolica* Fisch. ex Ledeb.: (*1*) ootheca on the bark underside removed from the tree, 9.IV.2022; (*2*) hatching of nymphs, 19.IV.2022; (*3*) the II instar nymphs on the bark underside, 25.IV.2022; (*4*) a freshly molted III instar nymph, 3.V.2022.

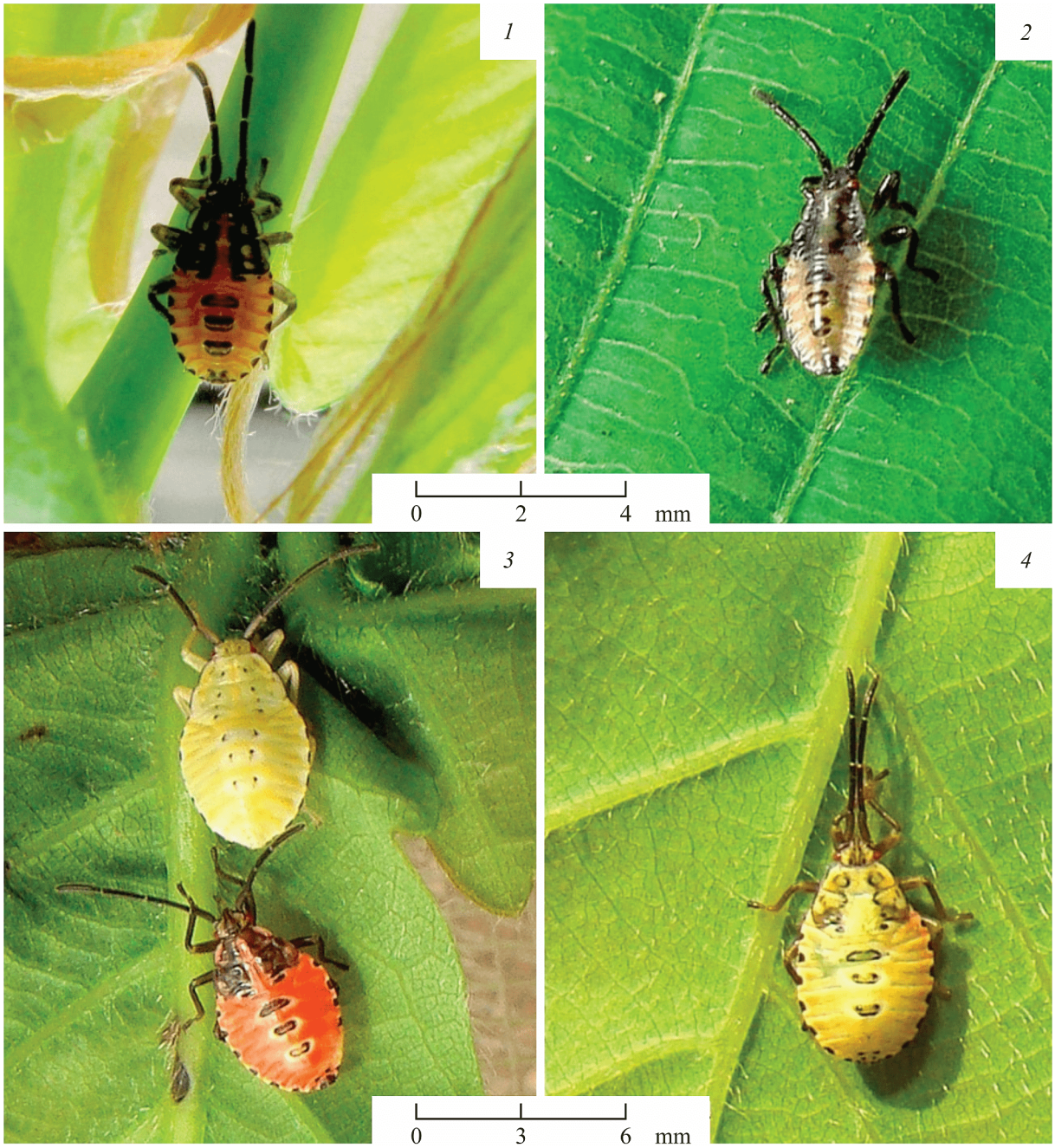

Fig. 3. Coloration variants in nymphs of *Urostylis annulicornis* Scott: (*1*, *2*) III instar; (*3*, *4*) IV instar.

1–2 days after molt (Fig. 3, *1*, *2*). The nymphs switched completely to sucking cell sap from the unfolding leaf laminae. They fed on both sides of the leaves and at the bases of the unfolding buds, but did not get inside the buds. The nymphs became more active by the middle of the first 10 days of May, so that on May 7, 2022 the clutches located under the bark were completely abandoned, with only wet spots marking the remains of the gelatinous coating. Starting with the III instar, the nymphs ascended higher into the oak crown and became difficult to observe. The duration of the III instar varied from 10 to 12 days ($m = 11$).

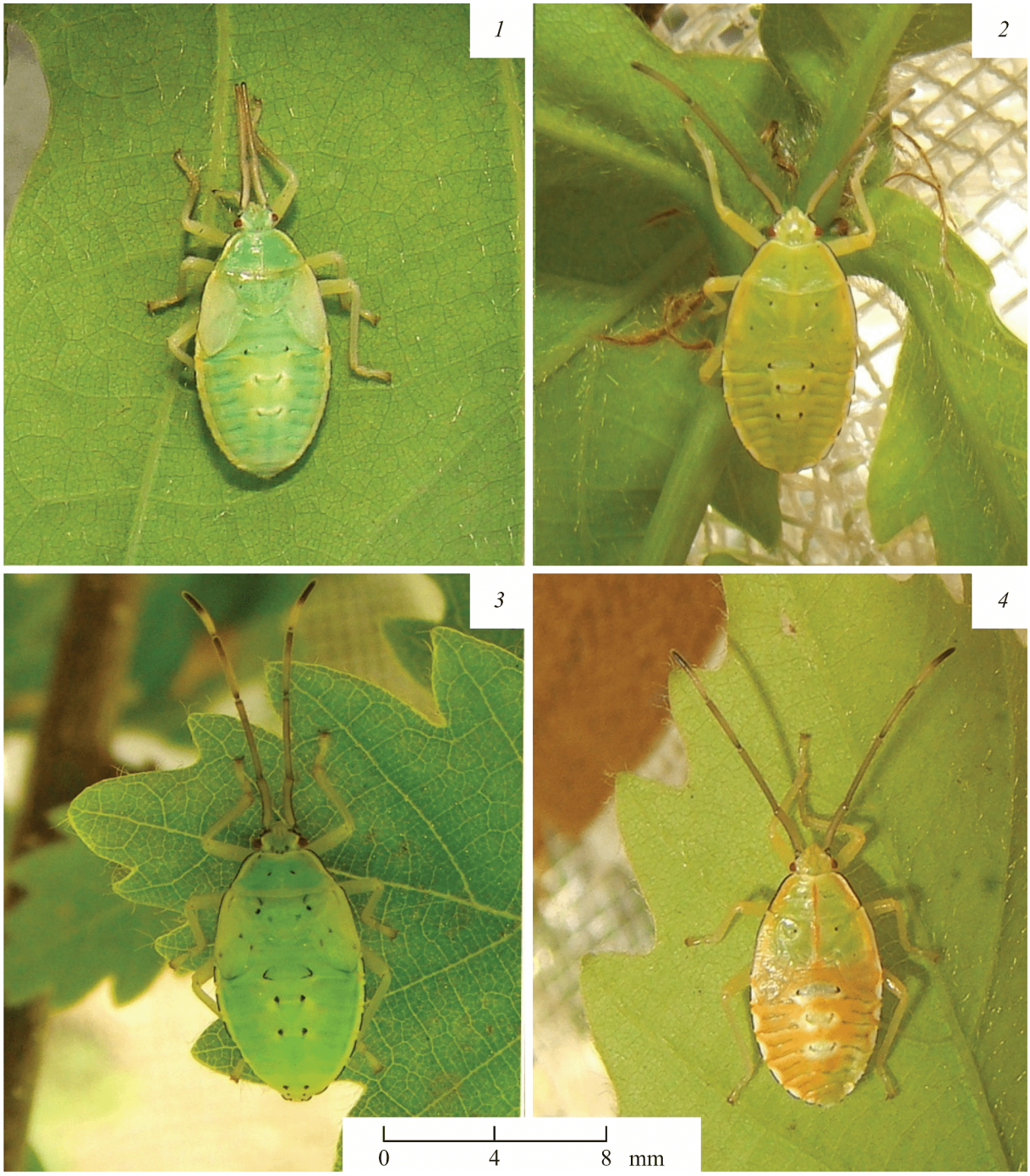

Fig. 4. Coloration variants in the V instar nymphs of *Urostylis annulicornis* Scott.

The IV instar nymphs were recorded from mid-May to the beginning of the last third of May. They had an elongate-oval body 4–7 mm long. The dark spots on the head, thorax, and abdominal segments turned paler, their edges became blurred, while the abdomen retained its reddish or grayish-yellow coloration (Fig. 3, *3*, *4*). The nymphs fed mainly on the underside of young unfolded leaves, clinging to them very tenaciously. Their

motor activity was generally low. The duration of the IV instar varied from 10 to 13 days (m = 12).

The V instar nymphs appeared in the middle or at the end of the last third of May. They had an elongate-oval body 8.0–8.9 mm long. Their coloration was green with a more or less pronounced yellow or pinkish tint, without dark spots (Fig. 4). The nymphs fed on both sides of the leaves; their motor activity was low, similar to the preceding instar. The duration of the V instar varied from 22 to 26 days (m = 24).

The nymphs started molting to adults in mid-June and continued until the end of June (Fig. 5). A study of the labels of collection specimens and the collection dates recorded in the literature has shown that adult bugs can be found in Primorskii Territory from the last 10 days of June to the end of August, with occasional specimens recorded even in early October. Species of the genus *Urostylis* are usually represented by single specimens in samples, because their nymphs and adults live mostly in the tree crowns.

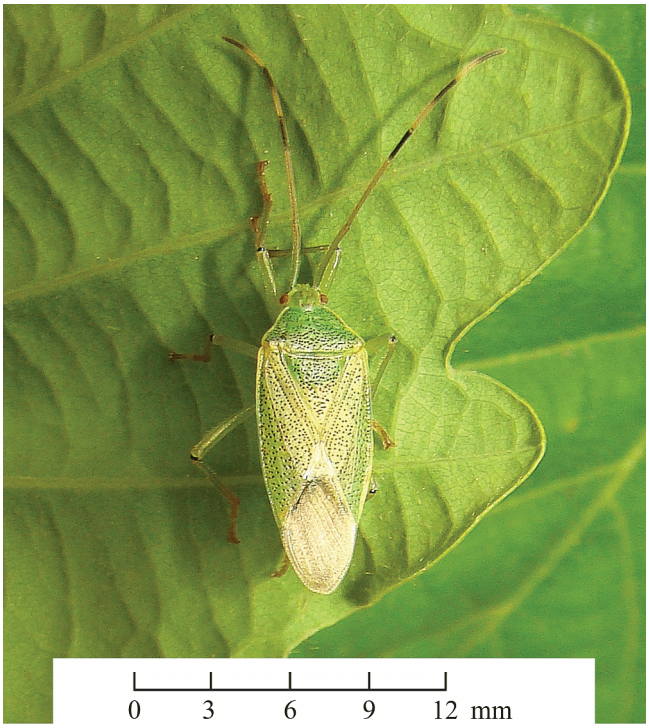

Fig. 5. *Urostylis annulicornis* Scott, a male molted on 21.VI.2022.

To study the timing of nymphal development in *Urostylis* bugs, we also used the material of Yu.A. Semeikin, who photographed egg clutches under the oak bark and the earliest nymphs of *Urostylis* sp. near Akademgorodok and the Botanical Garden of Vladivostok in 2015 and 2016. The clutches in his photos are somewhat different in shape from those we found; they are dated from March 31 to April 9, and the earliest nymphs appear in the photos from April 10 to April 25–28. Yu.A. Semeikin noted that the clutches were located in the areas with peeling bark around the trunk, almost from its base to a height of 1.5 m. According to his records, the nymphs were no longer found at the clutches after May 10 (i.e., they had left the clutches and switched to feeding on cell sap). His photo taken in May 16 already shows the nymphs on the unfolding oak leaves.

Molting behavior. The II instar nymphs of *U. annulicornis* kept in a cage molted on the inner surface of the bark fragment. The molting process took 60–65 min, including 13–15 min needed for shedding the exuvia. The nymph ready to molt positioned itself horizontally without moving away from the clutch. Then it crawled out of the exuvia to a distance equal to its body length, turned by 90–180°, and stayed in this position until its integuments were fully pigmented (see Fig. 2, *4*). Under natural conditions, the nymphs occupying the upper side of the oak leaf also molted on a horizontal surface. Their molting took 60–65 min, after which the nymph stayed near the exuvia. Its integuments darkened in 47–50 min.

The molting of the III and IV instar nymphs and the final molt to the adult took place mostly on the underside of the oak leaves. The nymph suspended itself upside down until it was completely released from the exuvia, and then stayed on the leaf underside.

DISCUSSION

The Japanese researchers observed the hatching of the earliest nymphs on the islands of Shikoku (33°45′N, 133°30′E) and Honshu (36°02′N, 140°06′E) in February (Kobayashi, 1965; Kaiwa et al., 2014). In contrast, in the south of the Russian Far East (Primorskii Territory, 43°37′N, 132°13′E), the earliest nymphs were recorded in late March and the first 10 days of April.

Fig. 6. Leaves of *Quercus mongolica* Fisch. ex Ledeb. damaged by nymphs and adults of *Urostylis annulicornis* Scott: (*1*) young leaf laminae after feeding of the II instar nymphs; (*2*) dry yellow-brown spots on leaf laminae after feeding of the nymphs and adults.

The nymphal stage of *U. annulicornis* lasted from 9.IV to 25.VI.2022 and was completed in 54–77 days (m = 65.5) at the mean daily air temperatures varying from –4.1 to +29.4°C (m = 12.7; n = 9). The duration of individual instars in *U. annulicornis* was as follows: 12–14 days for the I instar (m = 13), 9–12 days for the II instar (m = 10.5), 10–12 days for the III instar (m = 1), 10–13 days for the IV instar (m = 12), and 22–26 days for the V instar (m = 24). The final molt to adults was observed from 16.VI to 25.VI.2022 (4 ♂, 5 ♀).

The sucking of cell sap by bugs, starting with the II instar nymphs, changes the appearance of the affected young leaf laminae (Fig. 6, *1*). Dry yellow-brown spots subsequently appear on the leaves, and normal vegetation of the oak plant can be disrupted in case of extensive damage (Fig. 6, *2*). Under natural conditions, the harm caused by these bugs is noticeable only during their outbreaks.

ACKNOWLEDGMENTS

We are very grateful to N.N. Vinokurov (Institute of Biological Problems of Cryolithozone, Siberian Branch of the Russian Academy of Sciences, Yakutsk) and M.E. Sergeev (Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far Eastern Branch of the Russian Academy of Sciences, Vladivostok) for the provided label data of *U. annulicornis* from the collections of ZIN and the Federal Scientific Center, and to P. Kment (National Museum, Czech Republic) for the provided literature. We thank the anonymous reviewer and B.A. Korotyaev (ZIN) for advice and critical comments during preparation of this paper. We remember with gratitude Yu.A. Semeikin (Vladivostok) for his keen interest in insects and for providing photos and other information on the bugs.

FUNDING

The research was carried out within the framework of the state assignment of Ministry of Science and Higher Education of the Russian Federation (theme No. 121031000120-9).

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest. The authors declare that they have no conflict of interest.

Statement on the welfare of animals. All the applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All the procedures performed in studies involving animals were in accordance with the ethical standards of the institution or practice at which the studies were conducted.

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