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Life-history of *Gnopharmia kasrunensis* Wehrli, 1939 and *G. colchidaria* Lederer, 1870 (Geometridae, Ennominae) and their distribution in Iran, with first host-plant records for the genus

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Abstract. For the first time, observations on the life-history of the little known species *Gnopharmia kasrunensis* Wehrli, 1939 and *G. colchidaria* Lederer, 1870 are reported; eggs, larvae, pupae, adults and habitats are illustrated. Suitable differential features for a correct identification of both Iranian *Gnopharmia* species as well as a distribution map are provided.

Zusammenfassung. Erstmals wird über Beobachtungen zur Biologie der wenig bekannten Arten *Gnopharmia kasrunensis* Wehrli, 1939 und *G. colchidaria* Lederer, 1870 berichtet. Eier, Larven, Puppen, Imagines und ihre Lebensräume werden beschrieben. Für die korrekte Bestimmung der beiden iranischen *Gnopharmia*-Arten werden geeignete differentialdiagnostische Merkmale sowie eine Verbreitungskarte vorgelegt.

Key words. *Gnopharmia kasrunensis, colchidaria*, biology, distribution, Iran

INTRODUCTION

The genus *Gnopharmia* Staudinger, 1892 belongs to the tribe Macariini (Ennominae) (Wehrli, 1953: 565; Scoble & Krüger 2002) and consists of several species which are difficult to determine by external means only. Parsons et al. (1999) list thirteen species in this genus. At present, *Gnopharmia* is in the process of taxonomic revision by the author. By discovery of one new species and five synonymies, the number of valid species in the genus has been reduced to nine. All species occur in the Middle East and Asia Minor, their geographic range extending from Turkey to Pakistan. Five of the species occur in Iran. Our present knowledge on the biology and distribution of *Gnopharmia* species is very poor, partly due to difficulties of their correct identification. In the original descriptions of species in this genus (e.g. Ebert 1965, Erschoff 1874, Lederer 1870, Staudinger 1892, Wehrli 1938, Wehrli 1939, Wehrli 1941, Wiltshire 1967, Wiltshire 1970) no host plant records or notes about their biology are given. Prout (1915) listed three *Gnopharmia* species and six subspecies, and Wehrli (1953) mentioned seven species (and 11 subspecies). Both described the external features and Wehrli also characters of their genitalia, but they did not mention host plants or larval stages. The host-plant index published by The Natural History Museum, London (HOSTS, 2007), also does not record any host plant for species of the genus *Gnopharmia*.

After a number of unsuccessful breeding experiments with *Prunus* spp. and other Rosaceae species by various lepidopterists, the first correct suggestion about the host plant of *Gnopharmia* was made by Bernd Müller (Berlin; pers. comm.), who assumed the wild Almond which occurs abundant in the habitats where *Gnopharmia* species occurs (*Prunus*, subgenus *Amygdalus*; Rosaceae). The first breeding of a *Gnopharmia* was made by Robert Trusch (Karlsruhe; pers. comm.) in 2008 with material from East-Iran (Prov. Ostān-e Khorāsān, Birjand, Kuh-e Mirza Arab, 2.040 m a.s.l); larvae were fed with leafs of wild Almond shrubs from the field in Iran, but the experiment had to be finished because of the lack plant material in Germany; the species of the reared larvae remained undetermined

During May and July 2009, the author collected females of *G. kasrunensis* (Fig. 13) and *G. colchidaria* (Fig. 14) at several localities in Iran. The present paper illustrates the larval stages of both species and gives an overview of their distribution.

MATERIAL AND METHOD

Females of *Gnopharmia* species have been collected at six Localities (Table 1) by using a light trap. For laying eggs,

they were caged inside small plastic boxes with tissue paper, eventually adding suitable plant material.

In Tole-Heidari valley (province Fars, south of Jahrom, N 28°28'56" E 053°23'09", altitude 1112 m a.s.l.) May 15, 2009, one female of *G. kasrunensis* has been collected (culture A, table 1). This habitat is very dry and there are scattered bushes of different plant species. *Prunus lycioides* (Rosaceae; det. H. Akhani and M. Yazbek) as a possible host plant is common. Three females of *G. kasrunensis* were found in Ras-Kuh (province Kerman, road Baft-Sirjan, 2 km after Baft, N 29°17'27" E 056°35'37", altitude 2540 m a.s.l.) May 20 to May 21, 2009 (cultures B, C and D, table 1). This locality near Ras-Kuh village has a southeast-facing aspect (Fig. 1). The dominant plant species in the area is *Prunus scoparia* (det. H. Akhani and M. Yazbek) (Fig. 3 and 4). Material of this plant species has been added to the plastic boxes containing females. Two females of *G. colchidaria* have been collected at the mountains near the village Ab-Asemani, (province Fars, road from Estahban to Sarvestan, 20 km to Sarvestan, N 29°05'51" E 053°26'12", 1890 m a.s.l., May 22, 2009) (cultures E and F, table 1). This biotope has a northern exposure. *Prunus scoparia* was common here too, but there also were wild *Pistacia* trees (Anacardiaceae), many bushes of *Astragalus* (Fabaceae) and *Echinops* (Asteraceae), and several *Umbelliferae* spp. (*Umbelliferae*) (Fig. 2).

One female of *G. colchidaria* has been collected at Oshtorankuh (province Lorestan, between Dorud and Gahar lake, near Cheshmeh-Khorram, N 33°22'41" E 049°11'13 '', 2360 m a.s.l., Jun 22, 2009 (culture G, table 1). Five females of *G. colchidaria* were found at Gardaneh-Garrin (province Hamadan, 25 km to Nahavand from Noorabad, N 34°02'48" E 048°20'31", 2135 m a.s.l., Jun 25, 2009 (cultures H–L table 1) and at Khani-Sefid in Gardaneh-Khan near the border of Iran-Iraq (province Kordestan, 10 km from Saghez to Baneh, N 36°04'13" E 045°59'31", altitude 1976 m a.s.l., June 26, 2009) one female of *G. colchidaria* has been collected (culture M, table 1). No eggs or larvae have been observed in nature. Pupation of *G. kasrunensis* larvae (culture C) took place in the field (Iran), that of *G. colchidaria* (culture F) in the laboratory in Karlsruhe-Germany. In the field, the study of egg-morphology was done using a hand lens.

For this study the species have been identified by using male genitalia of freshly emerged adults. Identifying females by their genitalia is still problematic, as differences between species are minute and not fully understood at present. In some cases (e.g. *G. colchidaria*) only a female emerged and for identification genitalia dissection of simultaneously collected males were used. There are clear characters in the male genitalia, especially in the aedeagus, that can be used to separate the species. The aedeagus of *G. kasrunensis* is thicker and shorter (length 1.2–1.5 mm) than that of *G. colchidaria* (length 1.4–1.8 mm) and bears a group of 2–6 long, rod-like, subapical spines (length up to 0.3 mm) with rounded tip (Figs 24, 28). In contrast, the aedeagus of *G. colchidaria* has a subapical group of short, more or less cone-shaped spines (maximum 0.15 mm in length), 1–3 of them situated more distally and 2–3 (rarely up to 5) more basally (Figs 25, 29).

The tips of the 'octavals' (a pair of distal processes at sternite 8) are more strongly curved in *G. kasrunensis* (Figs 22, 26), than in *G. colchidaria* (Figs 23, 27). The genitalia capsules of both species are similar in size and shape,

Table 1. Species, date and number of collected females and their eggs, larvae and pupa, and dates of hatching and pupation, according to cultures.

Code of culture	Species	Date of collecting	Date of laying egg	N. eggs	Date of hatching	N. larvae	Date of pupation	N. pupa
A (loc. 1)	*G. kasrunensis*	15.5.09	17.5.09	27	21.–22.5.09	21	–	0
B (loc. 2)	*G. kasrunensis*	20.5.09	23.–24.5.09	37	27.–28.5.09	28	–	0
C (loc. 2)	*G. kasrunensis*	20.5.09	23.–24.5.09	14	27.–28.5.09	12	25.6.09	1
D (loc. 2)	*G. kasrunensis*	21.5.09	24.–25.5.09	28	28.–29.5.09	22	–	0
E (loc. 3)	*G. colchidaria*	22.5.09	28.–29.5.09	24	30.–31.6.09	17	–	0
F (loc. 3)	*G. colchidaria*	22.5.09	28.–29.5.09	33	30.–31.6.09	21	2.7.09	1
G (loc. 4)	*G. colchidaria*	22.6.09	25.6.09	18	29.–30.6.09	16	–	0
H (loc. 5)	*G. colchidaria*	25.6.09	27.–28.09	16	1.–2.7.09	16	–	0
I (loc. 5)	*G. colchidaria*	25.6.09	27.–28.09	45	1.–2.7.09	36	–	0
J (loc. 5)	*G. colchidaria*	25.6.09	27.–28.09	42	1.–2.7.09	38	–	0
K (loc. 5)	*G. colchidaria*	25.6.09	27.–28.09	17	1.–2.7.09	14	–	0
L (loc. 5)	*G. colchidaria*	25.6.09	27.–28.09	40	1.–2.7.09	36	–	0
M(loc. 6)	*G. colchidaria*	26.6.09	28.–29.6.09	9	2.–3.7.09	7	–	0

Plate 1. Figs 1–2: Biotopes of *Gnopharmia* species: 1, *G. kasrunensis* (Ras-Kuh, cultures B, C and D); 2, *G. colchidaria* (Ab-Asemani village, cultures E and f); Figs 3–4: host-plant: 3, tree of *Prunus scoparia*; 4, leaves and fruits of *Prunus scoparia*; Fig. 5: eggs of *G. kasrunensis* (culture C); Figs 6–8: larvae of *G. kasrunensis:* 6, L2; 7, L4; 8, L3; Figs 9–11: larvae of *G. colchidaria*: 9, L3; 10, L2; 11, L4.

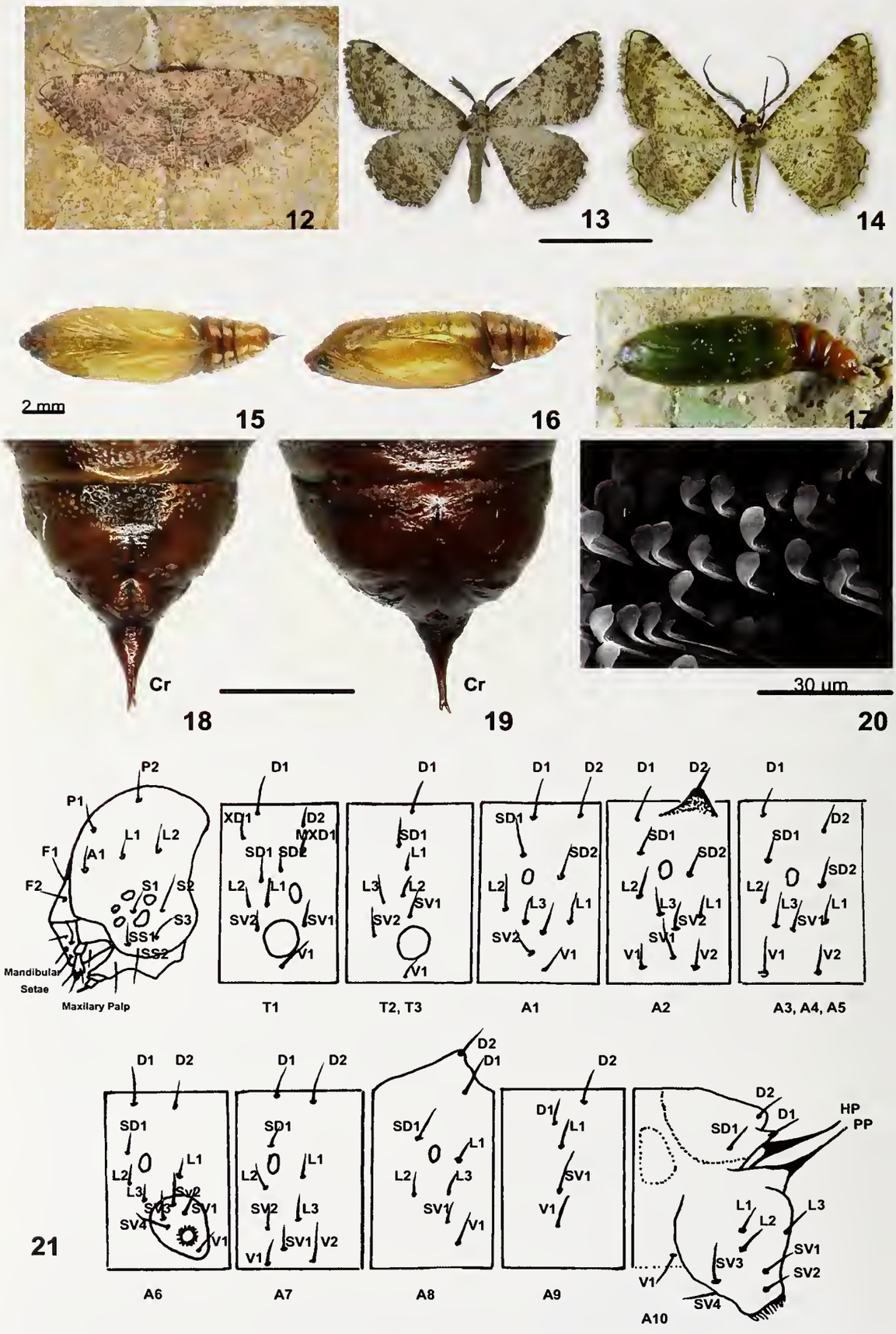

Plate 2. Figs 12–14: Adults of *Gnopharmia*: 12, *G. colchidaria* (female, freshly emerged; culture F); 13, *G. kasrunensis* (holotype, male); 14, *G. colchidaria* (male) (scale 1 cm); Figs 15–16: Pupa of *G. colchidaria*: 15, ventral view, 16, lateral view (scale 2mm); Fig. 17: Pupa of *G. kasrunensis*, ventral view (one day after pupation); Fig. 18: Pupa of *G. kasrunensis, posterior part* (male, ventral view; Cr: cremaster); Fig. 19: id., pupa of *G. colchidaria*, female (scale 1mm); Fig. 20: floricomous setae (distal part) on female ovipositor (scale on figure); Fig. 21: Setal map of *G. colchidaria* and *G. kasrunensis* larvae.

but the basal process of the sacculus is distinctly longer in *G. colchidaria*. In *G. kasrunensis* both of these projections seems to be equal in length (Figs 30, 31).

For SEM photography male genitalia have been dehydrated in 70%–96% and 100% ethanol. For drying with HMDS (1, 1, 1, 3, 3, 3-Hexamethyldisilazan) the HMDS-protocol (Oshel 1997) was used. According to this protocol the genitalia have been transferred from 100% ethanol to a 1:1 ethanol-HMDS mixture and then to 100% HMDS. The specimens were dried by evaporation of HMDS.

SEM photos were made using a Hitachi S-2460N SEM at Zoologisches Forschungsmuseum Alexander Koenig.

RESULTS

Rearing report and field observations

The female of culture-A (*G. kasrunensis*) laid eggs in a plastic box containing leaves of *Prunus lycioides*. Most larvae hatched from these eggs, but died because of lack of fresh food plants. Leaves of *P. lycioides* carried with us had dried out and no *P. lycioides* or another possible host plant was available. Females of cultures B–F (*G. kasrunensis*) laid eggs (*Prunus scoparia* was added to the containers) just two to three days after collecting and two days later, L1-larvae started to feed successfully.

Despite attempting to provide relatively stable conditions to the larvae, many of them died in different stages. Of 79 L1-larvae of *G. kasrunensis* in cultures B, C and D, just 42 survived to L2, and only 18 of them moulted again (after 7–8 days). L3-larvae were feeding almost continuously, but they were more active in the morning and in the afternoon. Larvae continued to perish during this stage as well. 6–8 days later just 7 larvae moulted to L4. They fed again for 5–6 days, but during this time all but one died. Fully grown (25.6.2009) the last remaining larva of this species (culture C) stopped feeding and rested under pieces of tissue paper in its container, then pupated (see Fig. 17), without spinning or producing a cocoon.

L1 stage of *G. colchidaria* took 7–9 days. Many of the larvae again died later during several instars. Of 38 L1-larvae (cultures E and F) just 24 moulted to L2. 5 larvae died in this instar. L3-stage took 7–8 days and of 19 larvae just three reached L4. The feeding period of the last instar is longer than that of the last species (9 days). Fully grown, just one larva pupated (Figs 15, 16).

At a temperature of 25–28° C, a male of *G. kasrunensis* emerged after 18 days (July 12, 2009; dissected). At a same temperature, one female of *G. colchidaria* emerged from pupa after 16 days (July 18, 2009; Fig. 12).

All seven females of the cultures G–M (collected from Lorestan, Hamadan and Kordestan provinces) laid eggs (a total of 187 eggs) which were brought to Germany, in order to find and to test suitable food-plants there. 163 L1-larvae hatched but none of the plants offered was accepted and all larvae died.

Host-plants

Prunus scoparia has been offered to the L1-larvae of *G. kasrunensis* and *G. colchidaria* (cultures B–F) and was readily accepted by all of them. This plant may be considered as the main food resource for both, *G. kasrunensis* and *G. colchidaria,* also under natural conditions.

To the L4-larva of *G. colchidaria* (cultures E and F), feeding on *P. scoparia* before, I offered two other Prunus species (*Prunus haussknechtii* C. K. Schneid. and *Prunus lycioides* (det. H. Akhani and M. Yazbek), but no feeding marks were found in either of them.

To L1-larvae of *G. kasrunensis* from Tole-Heidari (culture A) the common almond (*Prunus dulcis* (Mill.) D.A.Webb) and later *Prunus haussknechtii* C. K. Schneid. have been offered, but none of them was accepted. *Prunus scoparia* was not available at that time.

All larvae of the cultures G–M have been brought to Germany. It took 2 days to find a plant of *Prunus dulcis* (Miller) D.A. Webb. During this period I offered *Crataegus monogyna* Jacq., but it was not accepted by the larvae and more than half of them died. The others died in the next days because they also did not accept *Prunus dulcis*.

Morphology of preimaginal stages

Ovum

Ovum: Elliptical, surface rough, green in colour (just after deposition), turning red-ochre after one or two days (Fig. 5). Most of them were deposited separately in a vertical, upright position, but some were laid in clusters as shown in Fig. 5.

Under warm conditions, L1-larvae developed very quickly and emerged just after 4–5 days (table 1).

There is no significant difference in the shape or the structure between the eggs of these two species.

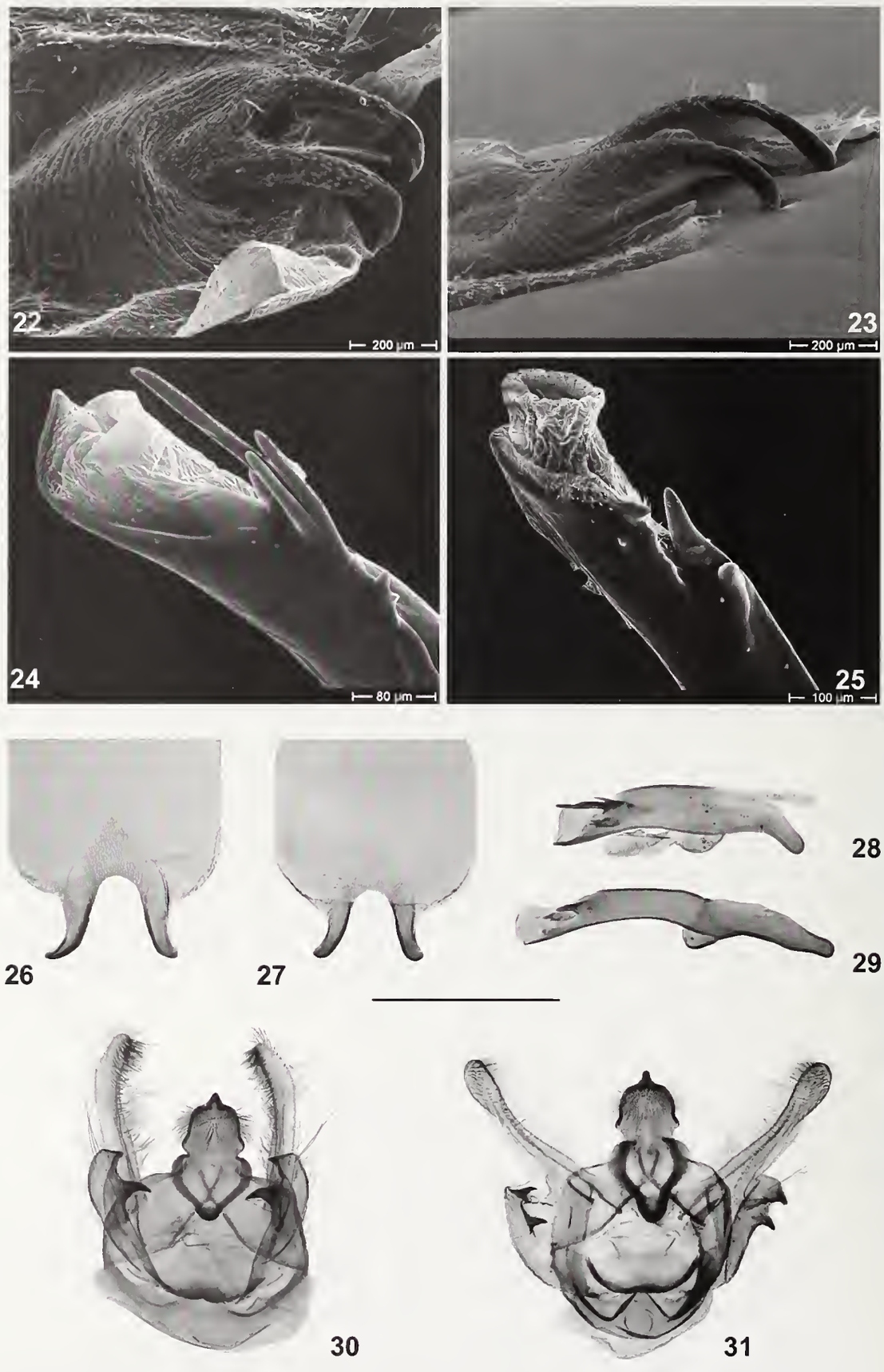

Plate 3. Figs 22–23: SEM photos of sternite A8, with 'octavals': 22, *G. kasrunensis*; 23, *G. colchidaria*; Figs 24–25: SEM photos of apical part of aedeagus: 24, *G. kasrunensis*; 25, *G. colchidaria* (scale on figures); Figs 26–27: Sternite A8: 26, *G. kasrunensis* (holotype, male); 27, *G. colchidaria* (male); Figs 28–31: male genitalia: 28, *G. kasrunensis* (aedeagus); 29, *G. colchidaria* (aedeagus); 30, *G. colchidaria* (genital capsule); 31, *G. kasrunensis* (genital capsule). Scale 1 mm.

Larval stage

***G. kasrunensis* Wehrli, 1939**

L1: 1.4–2.1 mm (5 days after haching) in length, with two longitudinal pale-brown bands on green background, starting from the posterior end of the medio-dorsal area and continuing to the head. Head and end of the body are brown. A longitudinal brown band, similar to the dorsal band, runs ventrally from posterior end to the head. The thoracic legs and abdominal prolegs are dark brown.

L2: (Fig. 6)**:** length 6.2–7.00 mm (11 days after hatching), brown medio-dorsal bands change (in compare to L1) from brown to more green, similar to the ground colour, but at the end of L2 the rest of brown bands are distinctly visible on two-thirds posterior of body. The brown ventral band vanishes toward head. In this stage, there are two dorsal processes at the base of the D2 seta dorsally on segment A2 (see Fig. 21). The tips of these processes are dark brown or black.

L3 (Fig. 8)**:** 9.6–10.5 mm (20 days after hatching), exhibits nearly the same colour patterns as found in the fully grown larvae. The dorsal area is completely green with medio-dorsal brown bands (from A10 to A6). Ventrally, the green colour is extended, but on A6–10 there are still soft brown colour band. During L3, the colour of the dorsal processes at the base of the D2 seta (of the A2 segment) changes from dark brown or black to brown.

L4 (Fig. 7): 19.2–25.8 mm (28 days after hatching), completely green in colour, with a longitudinal medio-dorsal brown bands running from the A10 to the A6 segment. The dorsal processes of the A2 segment are brown, but in two cases, changed to green.

***G. colchidaria* Lederer, 1870**

L1: 1.2–2.2 mm (7 days after hatching), coloration very similar to *G. kasrunensis*, but here longitudinal dorso-medial bands start from the posterior end and continue along two-thirds of the body dorsally (from A10 to A4–5).

L2: (Fig. 9)**:** 6.5–7.1 mm (12 days after hatching), brown dorso-medial bands continue to the head, the ventral band extends slightly to the lateral. The two dorsal processes of A2 are clearly dark brown to black in colour (like in *G. kasrunensis*).

L3: (Fig. 10) 9.7–10.7 mm (20 days after hatching), completely different in comparison with *G. kasrunensis***:** dorsal and ventral longitudinal brown bands extend laterally and the green colour is reduced to the lateral area. Black dorsal processes on the A2 segment are clearly visible.

L4: (Fig. 11): 19.2–26.1 mm (26 days after hatching), predominantly brown, with some yellow-green colour laterally and dorsally. The A2 dorsal processes are brown, like the surrounding area.

The position of the primary setae of the L4- larvae of both species does not exhibit any differences. (see setal map, Fig. 21). For nomination of seta used McGuffin (1977) and Stehr (2005).

Pupa

Pupae of both species are obviously very similar in size and colour. (Figs 15–19). They are slender, about 12.8–13 mm in length, the head section rather acute, almost triangular; the elongated cremaster (length 0.6 mm) bears two terminal spines of different length (right spine broken in fig. 19). Until the second day after pupation the colour remains green, and then changes to brown. The pupal exuvia is mid-brown, too. More material is needed in order to compare the pupal characters of both species thoroughly.

Distribution (Fig. 32). According to our present knowledge, *G. kasrunensis* and *G. colchidaria* occur sympatrically in most parts of the Zagros Mountains. *G. kasrunensis* has been described from Kazeroun (Fars prov., Iran) and is distributed in the central and eastern Zagros with some small populations in western Zagros and central Alborz. Only two specimens of this species were collected at Sayhakil in Musandam (Oman). *G. colchidaria* occurs in nearly all parts of Zagros, furthermore there are populations in south-eastern Iran, and in the Alborz (vic. Tehran, Qazvin, Zanjan, and Gilan). The species has been described from Helenendorf (East Azerbaijan, Transcaucasia; present name: Xanlar), and there are additional reports from Armenia (ssp. melanotaenia Wehrli, 1938) and other regions of S. Caucasus. The map is based on material present in the collections studied. Probably these two species have a wider distribution, but the author so far had no access to further material proving this.

Bionomic data. According to the analyzed label data, derived from several collections, *G. kasrunensis* has been collected between the second week of February and the second week of September. The flight period of *G. colchidaria* dates from early March to late October. *G. kasrunensis* flies at altitudes from 200 up to 2200 m, *G. colchidaria* from sea level to 2800 m. Both species probably are (at least) bivoltine in most places, but may be univoltine in the North of Iran and at higher elevations. Overwintering stage obviously is the pupa.

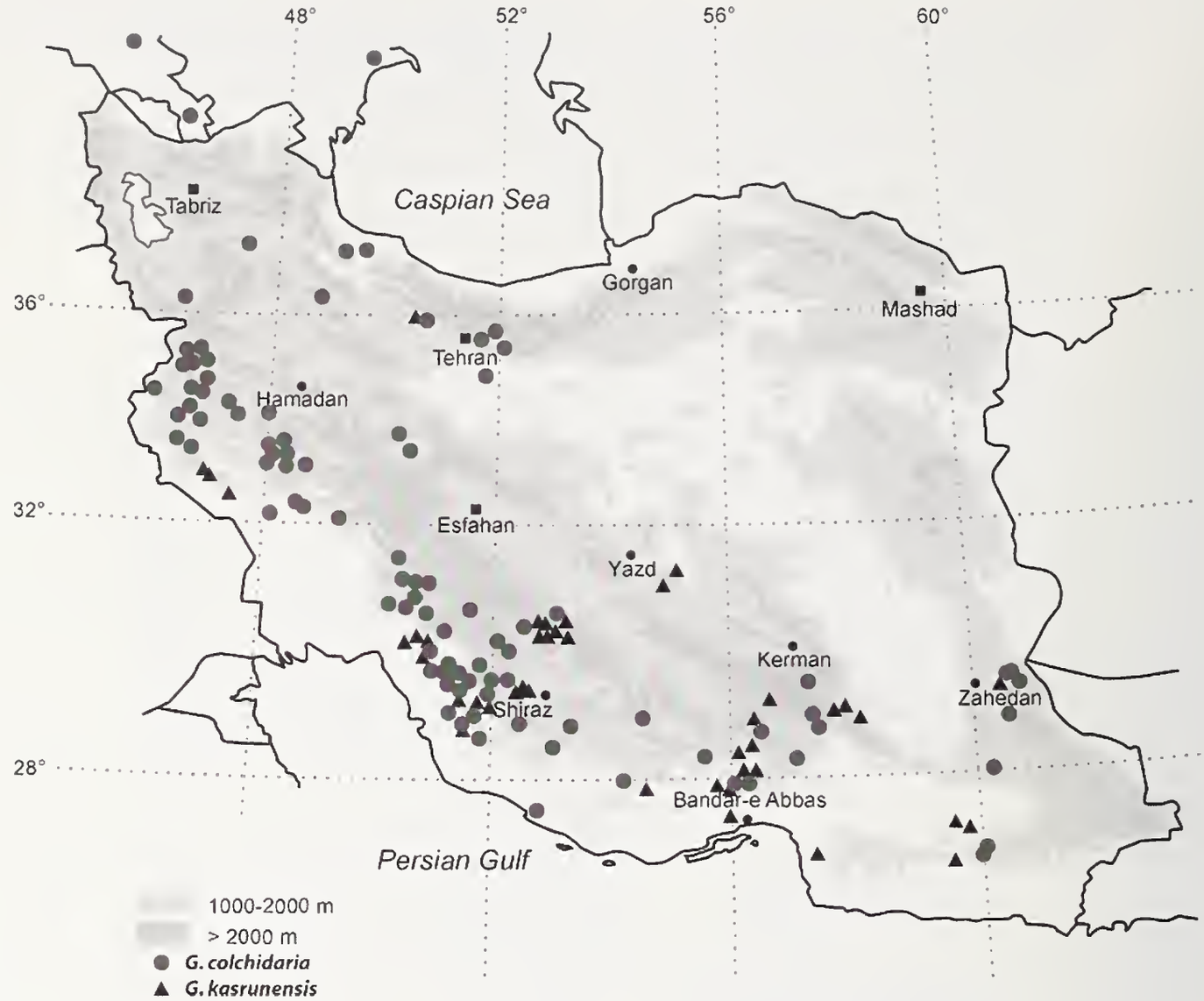

Fig 32. Distribution map of *G. kasrunensis* and *G. colchidaria* in Iran.

DISCUSSION

Despite intensive search on many *Prunus* shrubs in a number of Iranian localities for immature stages of *Gnopharmia,* no eggs, larvae or pupae were found in the nature. Of course, it is often difficult to find eggs of moths in the field, but in case of *Gnopharmia* these difficulties may also be related to the existence of a so-called "floricomus" on the ovipositor of *Gnopharmia* females. Numerous specialized ("scoop-shaped") setae (Fig. 20) on the papillae analcs probably enable the females to scratch particles from the surface of the bark to cover and camouflage the eggs. This behaviour has been observed in the W. European Ennomine species *Theria primaria* Haworth, 1809 (Stokoe 1948: 186, pl. 39:1), females of which have a very similar ovipositor with almost identical, specialized setae. This hypothesis is supported by the fact that the papillae anales of almost all females studied are spoiled with dust or bark-particles retained near the setal bases (Scoble & Krüger, 2002, D. Stüning, Bonn, pers. comm., unpublished).

Prunus scoparia as the most probable natural host plant of *G. kasrunensis* and *G. colchidaria* is well distributed in many parts of the Zagros Mountains. During the last years this plant has also been intensively grown by local people and became more widely distributed, as 'bitter almonds' became more frequently used by the pharmacological industry in Iran. *G. kasrunensis* and *G. colchidaria* fly sympatrically at many localities in Iran (Fig. 32). Lar-

vae of both species are very similar morphologically and the young larvae (L1, L2) are also without clear differences in colour and pattern. However, grown larvae (L3, L4) can be separated.

The reason for the high mortality of the larvae during all stages is not clear to us. Alteration of climate in the vehicle, low quality of the food plant, obstruction by sunlight or artificially damp environment (wet paper towels were provided to keep the food fresh) could have been the reason for bacterial or viral infection which killed the larvae.

Further studies on the biology of this interesting moth genus will be carried out during the 2010 collecting season.

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