Terrestrial Ecology and Behaviour
Research Article

ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., 68 (4), 2016: 535-540

Observation on Burrowing Behaviour, Oviposition and External Egg Morphology of *Gylippus* (*Gylippus*) *syriacus* (Simon, 1872) (Arachnida: Solifugae: Gylippidae)

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Abstract: The burrowing and oviposition of *Gylippus* (*Gylippus*) *syriacus* (Simon, 1872) are described. The external morphology of eggs is studied by scanning electron microscopy. Live females were collected from Şanlıurfa and Mardin Provinces in South-eastern Anatolia Region, Turkey, and maintained under laboratory conditions. This species constructs elongate oval-shaped burrows in both natural and laboratory conditions. The yellowish-white orbicular-shaped eggs, av. 1.125 mm in diameter, and the eggs‘ chorion surfaces bore truncate papillae.

Key words: Solifugae, Gylippidae, *Gylippus*, burrowing, oviposition, external egg morphology

Introduction

Solifuges are still poorly known arachnid order. Some extensive studies have contributed to our knowledge about Solifugae behaviour. Until now, burrowing behaviour, egg-deposition and egg-incubation were studied only by few researchers. Hutton (1843) recorded observations on the burrowing, egg-laying, deposition and incubation of *Galeodes vorax*. Turner (1916) studied burrowing habits, feeding behaviour and oviposition of *Eremobates formicarius*. Hingston (1925) also focused on the same behavioural observations on *Galeodes arabs*. Lawrence (1947, 1949) examined egg-laying and incubation of *Zeria caffra* and *Solpuga hostilis*. Muma (1966a) reported comparison of the burrowing habits on some species of Ammotrechidae and Eremobatidae. The egg-laying behaviour of *Eremobates durangonus* and the comparative egg structures of some other species of the family Eremobatidae were examined by Muma (1966b). Cloudsley-Thompson (1977) described the burrowing, feeding and mating behaviour of *Galeodes granti*. Gore & Cushing (1980) observed the burrow constructions of *Ammotrechula peninsulana* in its habitat. Thaler (1982) examined the eggs to first larvae as well as, first larval development of *Gylippus cyprioticus*. Wharton (1987) studied the oviposition, feeding and burrowing behaviour of the diurnal *Metasolpuga picta* and added a comparison with nocturnal species. Punzo (1998a, b) described the burrowing habit and life-cycle parameters of *Eremobates marathoni*. Punzo (1998c) summarised the general behaviour of burrowing, nest guarding of the gravid females, oviposition and features of the eggs with all the life parameters in the light of all these previous observations. Burrows are utilised for the digestion of food, oviposition, aestivation, ecdysis and protection against harsh environmental conditions.

Gylippus (*Gylippus*) *syriacus* (Simon, 1872) is a small nocturnal solifuge found in Cyprus, Iraq, Israel, Syria and Turkey (Harvey 2003, El-Hennawy 2007). In the present study, we describe in detail burrowing behaviour, oviposition and the external egg morphology in *Gylippus* (*Gylippus*) *syriacus*. In addition, we offer a comparative analysis regarding

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these features with other solifuges. The fine structure of the external egg morphology in a solifuge is shown for the first time.

Material and Methods

Two mature females and three juveniles of *Gylippus* (*Gylippus*) *syriacus* (Simon, 1872) were collected at the beginning of March 2013 from the Southeastern Anatolian Region of Turkey: 1♀, 2 juvs.; 37°03'8,8"N, 38°06'57,1"E , 663 m a.s.l., Arat Mt., Birecik District, Şanlıurfa Province, 14.03.2013 leg. M. Erdek; and 1♀, 1 juv.; 37°19'57.0"N, 40°48'58,8"E, 751 m a.s.l., Yeşilli District, Mardin Province, 15.03.2013, leg. M. Erdek. The species was identified following Birula (1913) and Roewer (1933). All individuals were maintained separately in the laboratory in plastic dishes (20 cm diameter and 15 cm high) containing a layer of soil about 2-3 cm in height. A small stone was added to provide a hiding place during the daylight hours and wet cotton wool for humidity. For feeding, larvae of Tenebrio molitor Linnaeus, 1758 (Coleoptera) were provided daily. Gravid females were regularly checked during daylight and night hours. For scanning electron microscopy (SEM) analysis, two eggs were cleaned and air dried. To clean the surfaces of the eggs, they were washed with a stream of 99.9% ethanol. The eggs were gold coated in a Poloran SC500 sputter coater. Morphological structures were studied and photographed at an accelerating voltage of 20kV with a JEOL JSM5600 scanning electron microscope.

Results

Burrowing behaviour

The gylippids were collected from under small stones in the field. The individuals were located in a position very close to the edge of the stones. The burrows of the female individuals were cylindrical and nearly the same width and length as the individuals themselves (Fig. 1A). In a few days, under laboratory conditions the females started constructing burrows (Fig.1C-D). Burrowing behaviour consisted of three stages: (1) biting-chewing, (2) raking and (3) plowing.

The biting-chewing stage was generally observed at the beginning of burrow construction, especially for crumbling the big soil molds and particles by chewing and rubbing the chelicerae. During the raking stage, the 2nd and 3rd legs were used, especially the 2nd pair of legs by curling them inwards from the joints between the tibia and the metatarsus. Dorsal metatarsal and tarsal spines vigorously raked the soil from front to back along the 3rd and 4th pairs of legs under the abdomen. After the raking, an approximately 1-2 cm soil mound was deposited on the posterior side of the female gylippid. The last stage was plowing. During this stage the soil mound was lowered by lifting and pushing forward with the open chelicerae. During burrow construction the 4th pair of legs was used for balancing. The pedipalps and 1st pair of legs were used for tapping and sweeping the soil mound. Burrow construction was completed with irregularly repeated biting-chewing, raking and plowing sequences. Firstly, the gylippid moved back and forth forming a hole, and then entered this hole by rotation, and the construction of an elongate oval shaped burrow was completed.

A few days after completing the burrow, the ova became distinctly visible firstly on the lateral side of abdomen. They were accumulated through the inner pleura wall of the whole abdomen. During the time between egg deposition and ovulation, the gravid female stopped feeding and retreated into the nest. Indeed, they did not eat the *Tenebrio* larvae, but only killed them. During daylight, water drinking behaviour was observed only two times: the gravid female chewed the wet cotton and in the second instance the female sucked the water on a stone directly via its rostrum, and the mesopeltidium and metapeltidium parts moved in a swallowing fashion (Fig. 1B).

Oviposition

Seven days after collecting from the original habitat (Mardin Province), the first egg mass, containing 23 whitish yellow eggs, was deposited on the soil surface in the early morning hours. After two or- three days, the colour of eggs darkened and they became dull and opaque. The unfertilised and shrivelled eggs were eaten by the female during the following two days. The same female started a new burrow construction on 30 March and the ova were distinctly visible postero-laterally in the abdomen one day later. The second egg clutch started to be laid in the late evening hours on 4 April. The female lay on her left side, and the pedipalps and legs curved inward and flexed. During spawning, the abdominal segments contracted from posterior to anterior. These abdominal contractions continued from the anal to the genital segment for each egg (Fig. 2).

Continuous spawning occurred during the laying of 34 eggs over an 80-90 minutes time period. After egg-laying, the right first leg and pedipalp twitched involuntarily for a few minutes. The individual had stopped eating for a few days before the start of egg-laying and about 14 hours later after spawning took its first food. The colour of the second egg mass dark-

Fig. 1. Female of *Gylippus* (*Gylippus*) *syriacus* in its natural habitat (Şanlıurfa Province) (arrow) (A).Water drinking behaviour (B). Burrowing behaviour before egg-deposition: raking with the pedipalps and legs (C), lifting and carrying soil with the chelicerae (D)

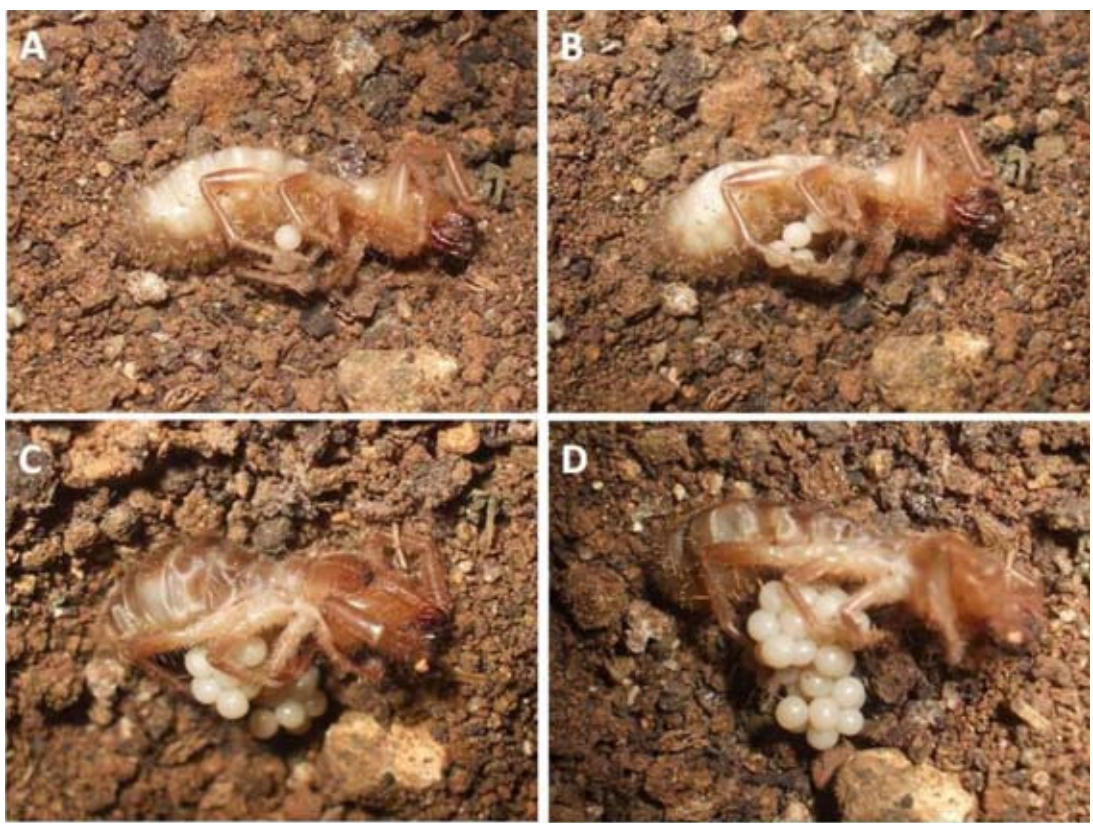

Fig. 2. Oviposition *Gylippus* (*Gylippus*) *syriacus* under laboratory condition (A-D)

ened and dulled after two days. The unfertilised and shrivelled eggs were also eaten by the female.

Egg morphology

The eggs were orbicular-shaped and averaged 1.125 mm in diameter. The surface of each egg chorion was covered by numerous, irregularly arranged truncate-shaped papillae (Fig. 3).

Discussion

Excavation of burrows consists of irregular sequence of biting, raking and plowing behaviour (Muma 1966a). Wharton (1987) claimed that the diurnal species *Metasolpuga picta* extensively used its second pair of legs with characteristic apical setae instead of the chelicerae for burrow excavation unlike some solifuges. In our study, female *Gylippus (Gylippus) syriacus* used its second pair of legs (especially the dorsal spiny side of metatarsus and tarsus) with approximately the same frequency as they used its chelicerae. The resultant soil mass was removed from under the solifugae by plowing with the chelicerae. Hutton (1843) observed that female *Galeodes vorax* strongly attack insects while defending her offspring (early instar nymphs) in the burrow. Also, Punzo (1998c) indicated that female galeodids and solpugids remain with their eggs and defend their nests against any threats. In the present study, following oviposition the female *G.*(*G.*) *syriacus* also attacked its prey (mealworms) without eating them, perhaps to prevent possible threats to her pregnancy and/or the eggs. Muma (1966b) reported that some eremobatid and ammotrechid females deposit their eggs in the deepest part of their burrows and abandon the nests while plugging the entrance. Cloudsley-Thompson (1977) also observed that *Galeodes granti* has a deep tube-like burrow. Considering the previous observations, Punzo (1998c) classified the conformations of solifugae burrows into two types: depression burrows and tube burrows. Unlike some ammotrechids, eremobatids and galeodids, gylippids do not construct deep burrows. Gylippids burrows are generally cylindrical and of a depth to cover their small body sizes under the stones as shallow depression burrows. *Gylippus* (*Paraylippus*) *monoceros* and *Gylippus* (*Hemigylippus*) *bayrami* also have similar cylindrical-shaped nests (M. Erdek, unpublished ob-

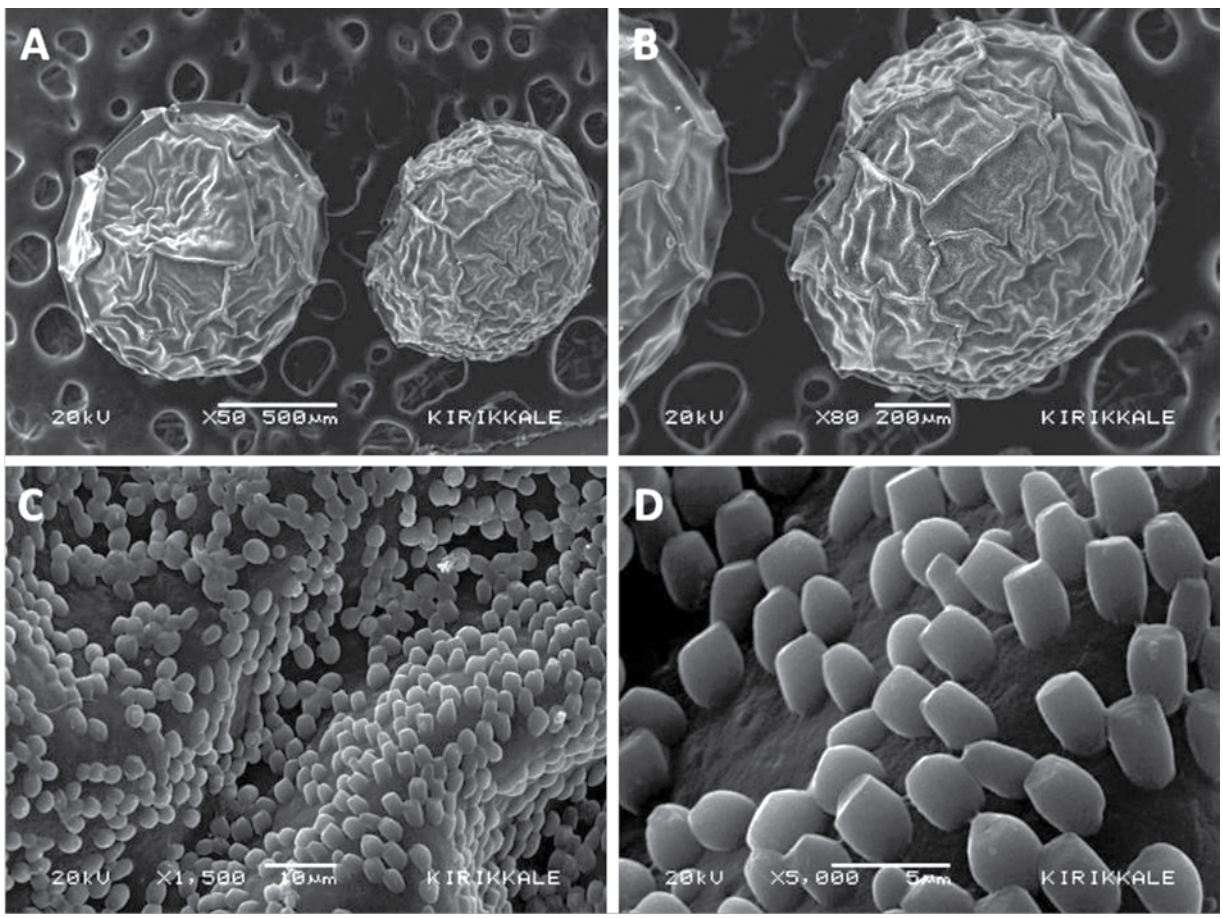

Fig. 3. Scanning electron micrographs of the eggs of *Gylippus* (*Gylippus*) *syriacus*: General view of the eggs (A-B) and truncate papillae on the egg chorion (C-D)

servations). We could speculate that burrow depths and constructions are variable and family-specific. According to Gore & Cushing (1980), burrow types appear to be sex-specific; in particular males occupy depression burrows and females occupy deeper tube burrows. They also claimed that, at least during a part of their life cycle, sexual dimorphism with regards to burrow construction exists. In the present study such dimorphism was not observed: the male, female and subadult gylippids had almost the same shaped shallow depression burrows.

During egg deposition, the female typically lay on its side, as Lawrence (1949) observed for *Solpuga caffra* and *Solpuga hostilis*. The egg mass of *S. hostilis* (body size 44 mm) was counted as 192 eggs, each egg measured 2.9-3.3 mm in length and 2.9-3 mm in width. The numbers of eggs for *S. caffra* (body size 58 mm) were 94, measuring 2.7 mm in length and 2.4 mm in width (Lawrence, 1949). The egg masses of *G. (G.) syriacus* were counted as 23-34 eggs, each egg measured 1.125 mm in diameter (length/width ratio ~ 1). Thus, the egg size and number seem to be species-specific; large-bodied species had larger sized and more eggs than small-bodied species. Punzo (1998c) indicated that female solifuges deposit their eggs in their burrows and the females of some species remain with their eggs. In the present study the female gylippid did not care for her eggs and cannibalised them. Muma (1966b) also observed the egg cannibalism for *Eremobates durangonus* and *Eremochelis bilobatus*. Lawrence (1947, 1949) emphasised that there are pattern-markings on the surface of eggs such as streaks, patches and traces of pigments. Occurrence of this pattern marking may be evidence of the eggs‘ fertility. On the eggs of gylippids, these pattern markings were not observed, perhaps because the eggs are unfertilised. That would explain why its life-cycle stages could not be observed in detail. Punzo (1998c) also pointed out egg cannibalism in solifuges, especially of non-hatched eggs or those in an earlier stage of development. Klann (2009) studied very young oocytes in subadult females. The cells contained a large amount of glycogen, many mitocondria, microvilli, frequent golgi bodies, small vesicles and droplets produced during oogenesis. Klann (2009) emphasised that the vesicles include multilamellar bodies and different kinds of droplets such as lipid and protein yolks. It might be suggested that female solifuges eat their own unfertilised eggs in order to prevent loss of nutrients and to restart the ovulation cycle.

Eggs of *G.* (*G.*) *syriacus* have a truncate papillae ornamentation on the chorion, arrayed at different intervals. Each egg is glued to the adjacent one to form the cohesive egg mass during release from the genital opening. It may be suggested that the wet egg surface and truncate papillae or denticulate surface of each egg are effective for egg coherence. Muma (1966b) observed different microscopic chorion ornaments for different species: i.e. coarse, widely spaced-truncate papillae for *Eremobates durangonus* and *Eremochelis bilobatus*; weak, faint to invisible nodular papillae for *Eremobates nodularis*; moderately-spaced rounded papillae for *Eremobates palpisetulosus* and distinct series of fine nodular papillae for *Eremorhax magnus*. According to the existing studies and the present paper, the morphological characteristics of the eggs reveal some differences and similarities of ootaxonomic significance for different Solifugae families. The same is true for predepositional periods, incubation periods, egg shape, number, size and colour.

Acknowledgements: We wish to express our sincere gratitude to Dr. Alfredo V. Peretti (National University of Cordoba, Argentina) for his valuable scientific and linguistic improvements. Thanks also to Dr. Halil Koç (University of Sinop, Turkey) and Dr. Ersen Aydın Yağmur (University of Celal Bayar, Turkey) for their help during the field work. This paper is a part of the doctoral thesis of the corresponding author and has been supported by the Scientific Research Projects Coordination Unit of Kırıkkale University (Project number: BAP/2011-16)

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Received: 07.12.2015
Accepted: 10.08.2016