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Adult morphology and life cycle under constant temperatures of the predator *Rhyzobius lophanthae* Blaisdell (Col., Coccinellidae)

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Abstract

The external and internal morphological characteristics of the predator *Rhyzobius lophanthae* Blaisdell (Coleoptera, Coccinellidae) were studied. The head, antenna, thorax elytra, hind wings, legs and abdomen are described. The adult has an average length of about 2.5 mm and width of 1.8 mm. The flagellum of the antenna consists of 9 segments. The whole surface of thorax and elytra is covered by setae. The tarsus of the 3 legs is 3-segmented. An external morphological difference between male and female is the outline of the 5th sternite. The alimentary canal, the central nervous system, and the reproductive system of both male and female are also described. The testes consist of 10 follicles and the ovaries of 10 ovarioles. The life cycle of *R. lophanthae* was studied by rearing the predator on the diaspidid *Chrysomphalus aonidum* (Linnaeus). The duration of the development of the embryo, 1st, 2nd, 3rd, 4th larval instars, pupa and preoviposition period of adults were measured at 15, 20, 25 and 30 °C.

1 Introduction

The Australian native coccoidophagous predator, *Rhyzobius lophanthae* Blaisdell (Coleoptera, Coccinellidae), has been reported as an important natural enemy of most armored scale species of the family Diaspididae (Homoptera, Coccoidea) (Yus, 1973; Rosen, 1990). The importance of this predator against diaspidids, is attributed to its biological and ecological characteristics (Stathas, 2000a, b). Inundatory releases of *R. lophanthae* in nature are recommended in the application of IPM programs (Katsoyannos, 1996).

Despite the importance of *R. lophanthae,* only few morphological studies have been conducted about this predator and published data are very rare. Smirnoff (1950) gives some data on the morphology of the eggs and refers to the way females lay eggs in nature, under scale covers of diaspidids. Ricci (1983) gives some details on the morphology of the immature stages of the predator. He describes the chaitotaxy of head, thorax, and abdomen on 4th instar larva and pupa. Morphological characters of larvae of all instars of *R. lophanthae* are given in further studies (Stathas, 2001b).

As far as the biology and ecology of *R. lophanthae* are concerned, there are some data in the literature. These studies relate to the prey consumption and fecundity of the predator (Stathas, 2000a), its development on the diaspidids *Aspidiotus nerii* Bouché and *Aonidiella aurantii* (Maskell) (Stathas, 2000b; 2001b), and its ecology and phenology in Greece (Stathas, 2000b; 2001a).

In the present study, it was considered important to present additional data on the morphology and biology of *R. lophanthae*. These data concern the external morphology and anatomical characteristics of the adults of the predator, such as the alimentary canal, the central nervous system and the reproductive system of both male and female.

The duration of the life cycle of the predator was studied under constant temperatures on the diaspidid *Chrysomphalus aonidum* (Linnaeus). The low temperature thresholds and thermal constants of each developmental stage of *R. lophanthae* were also determined.

2 Materials and methods

The individuals of *R. lophanthae* used the study of morphology were reared on potato tubes infested by *Aspidiotus nerii* Bouché (Homoptera, Diaspididae), in an insectary, at 25 °C and 18 h light per day. The dimensions of 25 male and 25 female adults were measured under stereoscope microscope. The study of the anatomy of *R. lophanthae* was made by dissecting adults in Ringer solution (Langeron, 1949).

Measurements of the duration of the life cycle were made under 15±1, 20±1, 25±1, and 30±1 °C. The relative humidity was 65±5 % with a 16:8 (L:D) photoperiod at all 4 temperatures. The length of egg, larval, and pupa stages, the preoviposition period, and adult longevity were measured under these conditions. Data were taken from 30 individuals in each case. Whenever a larva died, the mortality was recorded and the larva replaced, so as to have always 30 larvae in each treatment. Each individual was reared separately in a cylindrical plastic cage (13 cm diameter by 17 cm height). Measurements took place once a day. Insects were fed on nymphs of *Chrysomphalus aonidum* infesting potato tubes. The developmental thresholds and thermal constants were determined for each immature stage. For each stage of development, the regression equation of the development ($y = a+bT$) and the coefficients of determination (R^2) are given. The thermal constant, K, is determined as 1/b (Stathas, 2000b).

3 Results

3.1 External morphology

The shape of the adult is quite elliptic. Females had an average length (Mean ± SD) of 2.5 ± 0.09 mm and width of 1.8 ± 0.09 mm, while males measured 2.4 ± 0.08 mm and 1.74 ± 0.07 mm, respectively.

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3.1.1 Head

The head is reddish-brown. The front part of the head capsule (prelambium, mentum and compound eyes) is visible from above, while the back (submentum and gula) is hidden by the pronotum. The whole surface of the head is covered by setae. The antenna consists of the scape, pedicel and flagellum, which is 9-segmented and covered by setae. Scape, pedicel and the last three segments of the flagellum are broader than the rest (fig. 1).

3.1.2 Thorax

Pronotum is well developed, reddish-brown in color like the head, and covered by setae all over its surface. The covering setae are denser towards the periphery and directed to the front. The mesothoracic scutellum is the only visible part of the rest of the notum. It is between the base of the elytra, has the shape of an inverted triangle, black-brownish and covered by dense setae directed to the back. The remaining meso- and metanotum are connected more strongly than pronotum with mesonotum and covered by the elytra.

The sternum is well sclerotised, covered by setae, denser towards the periphery and directed to the back. Prosternum is split longitudinally to two areas by the prosternal carina which is between the fore legs and is Δ shaped. Mesosternum is connected tightly to metasternum, while it is clearly separated from prosternum. Mesosternum is split from mesosternal carina which has the shape of inverted trapezium. A straight hollow line also splits metasternum.

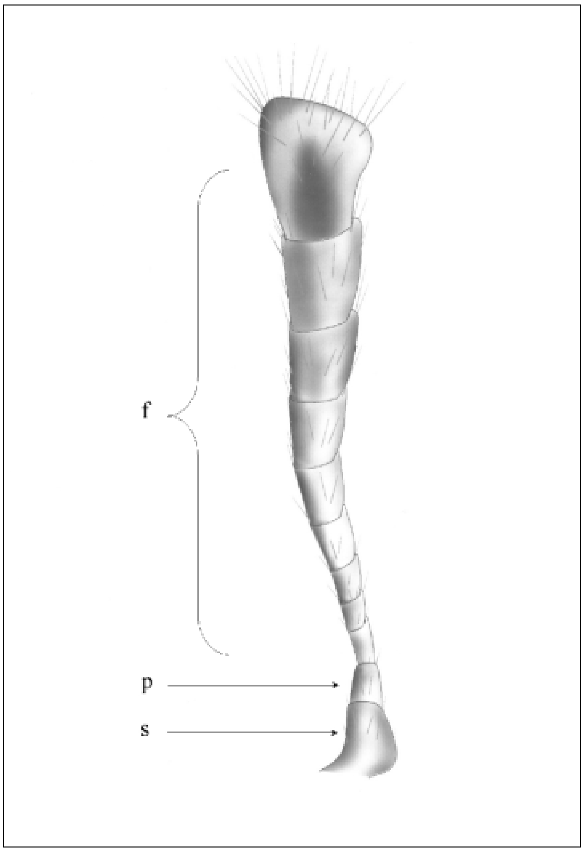

Fig. 1. Antenna of adult of *Rhyzobius lophanthae.* f: flagellum, p: pedicel, s: scape.

3.1.3 Wings

The elytra are metallic brownish-black and covered uniformly all over their external surface by two kind of setae:
– short and thin, dense setae similar to the body setae.
– long (about twice in length than the above) and thick, sparse.

The ventral part of the elytra (epipleuron) is broader in the middle and narrows apically.

Hind wings, are membranous, well developed and functional. The veins Radius, Media and Cubitus are well developed.

3.1.4 Legs

Legs are well developed and of the running type. Over their whole length, they are covered by setae similar to that of the thorax, directed to the tarsus. The tarsus of all legs consist of 3 tarsomeres (tarsal type 3–3-3), with bilobed claws that have indentations in the middle.

3.1.5 Abdomen

The abdomen is covered ventrally by the elytra except for the last uronotum that often protends to the back. Tergites are slightly sclerotized, except for the last, which is well sclerotized and covered by setae directed to the back, denser peripherally. A pair of spiracles is located on each segment.

Sternites are reddish-brown and covered by setae directed to the back, denser peripherally. The 5^{th} and especially the 1^{st} sternites are longer than the rest. The 1^{st} sternite is partly covered from the coxa of the hind legs. The femoral lines are U-shaped (fig. 2). The outline of the 5^{th} sternite ($7^{th} = 5^{th}$ visible) is useful to distinguish the sex. In females, it is arched, while in males, it has a recess like open wide U (fig. 2a, b).

3.2 Anatomy

The study of the anatomy of adult *R. lophanthae,* comprises the description of the alimentary canal, central nervous system, and reproductive organs of both sexes.

3.2.1 Alimentary canal

The alimentary canal consists of the foregut (stomodeum), midgut (mesenteron) and hindgut (proctodeum). In the foregut, there is the pharynx which is cylindrical,

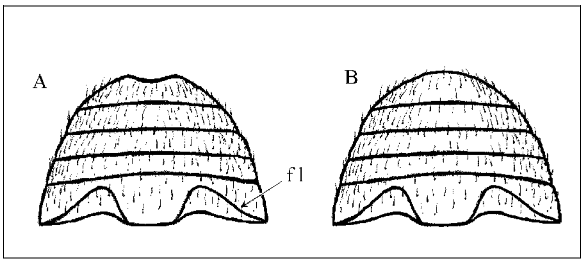

Fig. 2. Venter of abdomen of male (A) and female (B) of *Rhyzobius lophanthae.* fl: femoral line.

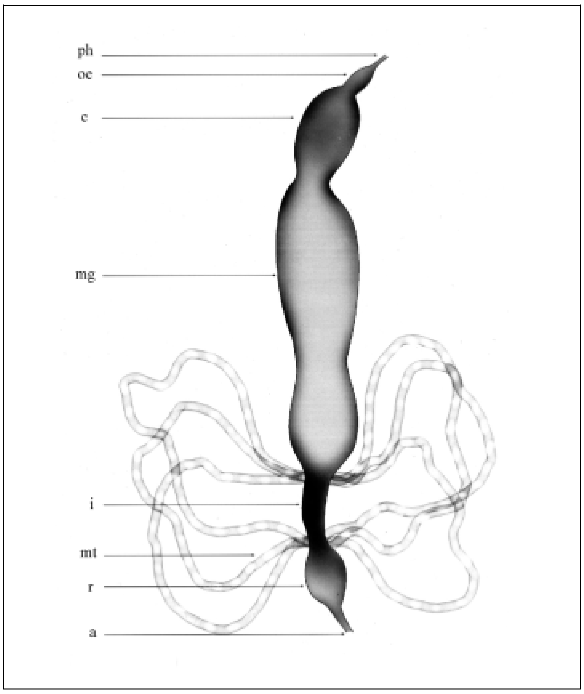

Fig. 3. Alimentary canal of adult of *Rhyzobius lophanthae.* ph: pharynx, oe: oesophagus, c: crop, mg: midgut, i: ileum, mt: malpighian tubules, r: rectum, a: anus.

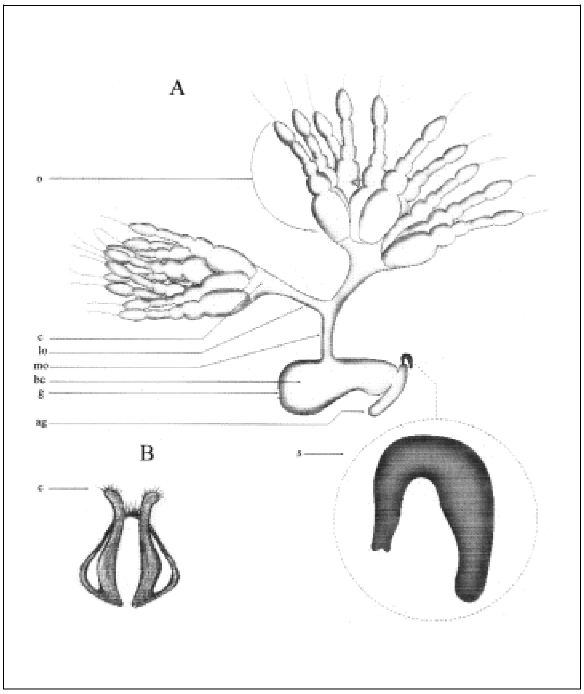

Fig. 5. Reproductive system of female of *Rhyzobius lophanthae.* 5A. o: ovariole, c: calyx, lo: lateral oviduct, mo: median oviduct, bc: bursa copulatrix, g: gonopore, ag: accessory gland, s: spermatheca. 5B. Female genitalia sclerites, c: coxites.

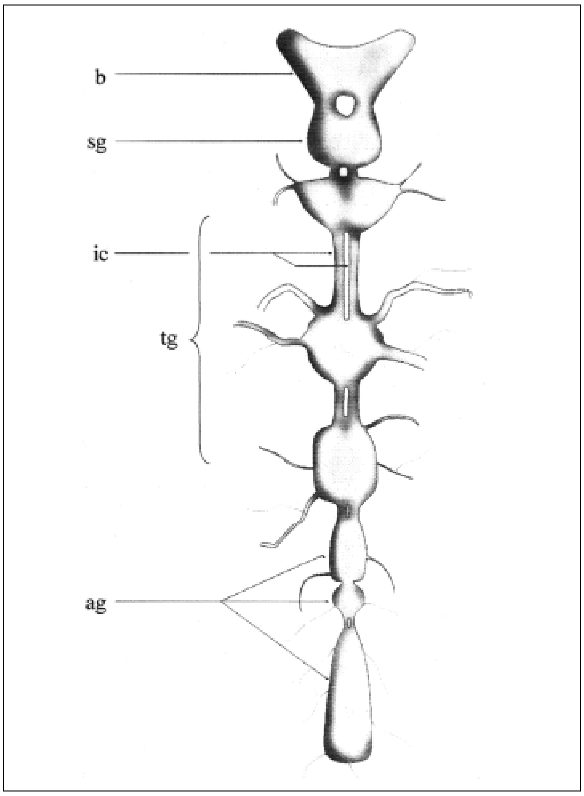

Fig. 4. Central Nervous System of adult of *Rhyzobius lophanthae.* b: brain, sg: suboesophageal ganglion, ic: interganglionic connectives, tg: thoracic ganglia, ag: abdominal ganglia.

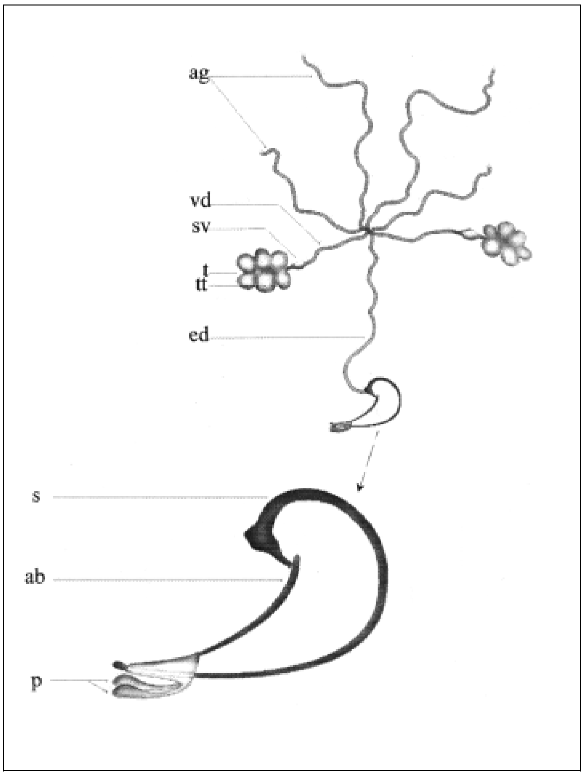

Fig. 6. Reproductive system of male of *Rhyzobius lophanthae.* ag: accessory glands, t: testis, tt: testis tube, sv: seminal vesicle, vd: vas deferens, ed: ejaculatory duct, s: sipho, ab: apophysis basal, p: paramera.

Table 1. Development of *Rhyzobius lophanthae* under constant temperatures on the scale *Chrysomphalus aonidum*.

Stage	Temperature							
	15 °C	20 °C	25 °C	30 °C	t (°C)	K	Regression lines	R^2
Egg								
D	18.8	11.2	7.5	6.1	7.9	133.3	y = 0.0075x – 0.0594	0.9957
S.D.	2.11	1.14	0.68	0.32				
(n=30)								
First instar								
D	8.7	5.1	3.2	2.7	8.9	54.1	y = 0.0185x – 0.1647	0.9835
S.D.	1.00	0.12	0.25	0.26				
(n=30)								
Second instar								
D	5.9	3.6	2.5	1.8	8.9	39.1	y = 0.0256x – 0.2266	0.9927
S.D.	1.10	0.45	0.37	0.14				
(n=30)								
Third instar								
D	6.2	3.9	2.8	2	7.9	46.3	y = 0.0216x – 0.17	0.9929
S.D.	0.41	0.52	0.21	0.22				
(n=30)								
Fourth instar								
D	17.1	9.1	6.7	5.5	7.3	120.5	y = 0.0083x – 0.0608	0.9909
S.D.	1.90	1.08	0.44	0.95				
(n=30)								
Pupa								
D	15.2	8.0	6.0	4.6	8.1	101.0	y = 0.0099x – 0.0797	0.9957
S.D.	2.03	1.12	0.24	0.88				
(n=30)								
Preoviposition period								
D	14.7	7.0	5.3	4.0	8.8	84.7	y = 0.0118x – 0.1039	0.9918
S.D.	3.10	1.10	0.91	0.98				
(n=30)	(n=13)	(n=14)	(n=13)	(n=14)				
Total development of life cycle								
D	86.6	47.9	33.6	27.2	8.2	588.2	y= 0.0017x – 0.014	0.9989

(D: days, S. D.: Standard Deviation, n: number of individuals, t: temperature threshold, K: thermal constant, y = developmental rate, x = temperature, R^2: coefficient of determination).

the oesophagus that is broader, and the crop which is even broader (fig. 3). The midgut is the broader part of the alimentary canal. The hindgut consists of the narrow cylindrical ileum and the global rectum which ends at the anus.

The excretory system of *R. lophanthae* consists of 3 pairs of Malpighian tubules. Each tube arises from the pyloric region and reaches to the anterior part of the proctodeum (fig. 3).

3.2.2 Central nervous system

Figure 4 shows the central nervous system, consisting of the brain and the ventral nerve cord, which comprises the suboesophageal ganglion, 3 thoracic (pro- meso- and metathoracic) and 3 abdominal ganglia. The ganglia are connected by interganglionic connectives.

3.2.3 Reproductive system

Rhyzobius lophanthae is an oviparus and biparental species. The female reproductive system is shown in fig. 5. Each ovary is made up of 10 ovarioles. The accessory gland with the U-shaped spermatheca (fig. 5a) is attached to the bursa copulatrix. The female genitalia are shown in fig. 5b. The apex of the coxites is covered by setae.

Each testes of *R. lophanthae* includes 10 testis tubes or follicles (fig. 6). Two pairs of accessory glands are connected to the junction of the vas deferens. Paramera are partly covered by setae on their internal side.

3.3 Life cycle

The mean duration of the development of each immature stage and preoviposition period of *R. lophanthae* reared on *Chrysomphalus aonidum*, are shown in Table 1. The low temperature thresholds (t), thermal constants (K), linear regressions, which describe the relationships between developmental rate (y) and temperature (x), and the coefficient of determination (R^2) are also presented. The duration of the life cycle of *Rhyzobius lophanthae* fluctuated between 27.2 days (at 30 °C) and 86.6 days (at 15 °C), and the thermal constant of the competition of its life cycle, is 588.2 day-degrees. Among the immature stages of the predator, the highest mortality was recorded in pupae and the lowest in the larvae of the 1st instar (Table 2).

4 Discussion

In the literature, it is reported that *R. lophanthae* in nature completes 6 generations per year in Greece (Stathas, 2000b) and 7–8 in Morocco (Smirnoff, 1950).

Table 2. Mortality (%) of immature stages of *Rhyzobius lophanthae* during its rearing on the scale *Chrysomphalus aonidum,* under constant temperatures (n = 30).

	Mortality (%)					
	Stage					
(°C)	egg	L1	L2	L3	L4	Pupa
15	16.6	16.6	13.3	6.6	6.6	3.3
20	6.6	3.3	6.6	3.3	6.6	0
25	0	6.6	3.3	0	0	0
30	20	20	10	10	6.6	3.3

(L1, L2, L3, L4: 1^{st}, 2^{nd}, 3^{rd} and 4^{th} larval instar, respectively)

It is also reported that the predator continues its development during winter months and hibernates in all developmental stages in Georgia (RUBSTOV, 1952) and Greece (STATHAS, 2000b). The high voltinism and capacity of immature stages of *R. lophanthae* to continue their development during winter months could be attributed to the relatively low rates of its thermal constant (588.2 day-degrees) and low temperature thresholds (7.3 – 9.3 °C), respectively. Another study reported that the duration of the life cycle of *R. lophanthae,* when the predator was reared on the diaspidid *Aspidiotus nerii*, fluctuated from 23.9 days (at 30 °C) to 79 days (at 15 °C) (STATHAS, 2000 b). Furthermore, different mortality of immature stages has been recorded when the predator was fed on other diaspidid species such as *A. nerii* and *Aonidiella aurantii* (Maskell) (STATHAS, 2001 b). The above-mentioned differences could be explained by the influence of food on the development of the coccinellid predators (HODEK, 1973).

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