Rhyzobius lophanthae Prey Consumption and Fecundity

G.J. Stathas[1]

The daily and total prey consumption and the fecundity of the predator *Rhyzobius lophanthae* Blaisdell (Coleoptera: Coccinellidae) fed on the scale *Aspidiotus nerii* Bouché (Homoptera: Diaspididae) were studied under controlled laboratory conditions. The prey consumption of *R. lophanthae* was studied on larvae and on virgin adults, and the fecundity on mated females. For the development of the 1st instar larvae of *R. lophanthae* at 25°C, 1.2 adult female *A. nerii* were consumed; for the development of the 2nd, 3rd and 4th instar larvae, prey consumption was 2.7, 7.5 and 24.6 adult females, respectively. The duration of the larval development of the 1st, 2nd, 3rd and 4th instars was 3, 2.2, 2.7 and 6.2 days, respectively. *R. lophanthae* male and female adults consumed in their lifetime 390.6 and 672.3 adult female *A. nerii*, respectively. Thus, the male's daily prey consumption came to 7 and the female's to 12 adult female *A. nerii*. The average fecundity of *R. lophanthae* was calculated to be 633.7 eggs per female and the daily fecundity to be 18–25 eggs. The average longevity was 63.4 days for mated adult females and 119.4 days for unmated.
KEY WORDS: *Aspidiotus nerii*; Coccinellidae; fecundity; longevity; mating; predator; prey consumption; *Rhyzobius lophanthae*.

INTRODUCTION

The predator *Rhyzobius lophanthae* Blaisdell (Coleoptera: Coccinellidae) is one of the natural enemies of diaspidid scales. It is known as an effective natural enemy of these scales (9) and its inundative releases in nature are recommended in IPM programs (11). *R. lophanthae* has been reported to be an effective classical biocontrol agent in California (28), Italy (5,22), Argentina (20), Bermuda (4), Algeria, Tunisia, Morocco (19,22) and Georgia (18). Its presence is recorded also in other countries, such as Greece, where it spread from neighboring countries by ecesis (2,11). Because of its biological characteristics – including specificity of prey, fecundity and adult longevity, and of its ecological characteristics – such as lack of diapause, good mobility, rapid population development (5–7 generations per year) and lack of parasitism, *R. lophanthae* is a highly important natural enemy of most armored scale species (11,18,22).

The prey consumption and the fecundity of a predator can influence its effectiveness as biocontrol agent against its hosts (9). This is the reason why similar studies on prey consumption and fecundity have been made also on other predators, such as the coccinellids *Chilocorus bipustulatus* Linnaeus (24), *Chilocorus nigritus* (Fabricius), *Simmondsius pakistanensis* Rafig Ahmad and Chani, and the nitidulid *Cybocephalus semiflavus* Champion (1). Some data on prey consumption of *R. lophanthae* are presented

Received Sept. 28, 1999; received in final form March 20, 2000; http://www.phytoparasitica.org posting March 29, 2000.
[1]Benaki Phytopathological Institute, GR 145 61 Kifissia, Athens, Greece [Fax: +30-1-8077506; e-mail: gstathas@x-treme.gr].

in the study of Cividanes and Gutierrez (6), who formulated a metabolic pool model for the development of the predator on the diaspidid *Aspidiotus nerii* Bouché. Other data are given by Marin (14), who reared *R. lophanthae* on diaspidid *Pinnaspis aspidistrae* (Signoret). Honda and Luck (10) studied the influence of host scale morphology on *R. lophanthae* feeding behavior by measuring the consumption time of different development stages of the diaspidids *Aonidiella aurantii* (Maskell) and *A. nerii*. As far as *R. lophanthae* fecundity is concerned, there is little information about egg-laying or total fecundity, according to observations in nature (22).

Because of the severity of damage caused by diaspidids in the groves and the importance of *R. lophanthae* as a predator of these scales, further information was needed on prey consumption and fecundity of the predator (not included in existing references). The additional information concerns daily and total prey consumption in each larval stage, in adult females and males, as well as the pattern of oviposition.

MATERIALS AND METHODS

The initial population of *R. lophanthae* originated from Leonidion, Peloponnesus, Greece. Adults and larvae were collected from lemon and sour orange trees infested with the scale *Parlatoria pergandii* Comstock (Homoptera: Diaspididae). Then they were transferred to the laboratory in the Benaki Institute, Athens, and reared in cylindrical Plexiglas cages (30 cm in diameter, 50 cm in height). The scale *Aspidiotus nerii* Bouché (Homoptera: Diaspididae), infesting potato tubers and sprouts, was used as food. The eggs laid by females of the second generation of this rearing were used for the present study. The prey consumption and fecundity of *R. lophanthae* were studied under controlled laboratory conditions (25±1°C, 65±5% r.h. and 16 h light per day).

Prey consumption Measurements of both daily and total prey consumption were carried out on 25 larvae of *R. lophanthae* for each larval stage, as well as on 13 adult females and 12 adult males throughout their lifetime. Each individual was reared separately in a petri dish 9 cm in diameter and 1.6 cm high, and was fed only on adult females of *A. nerii*.

Fecundity Fecundity was determined for 25 females reared in male–female pairs throughout their lifetime. In case the male died before the female, it was replaced by another male. Each couple was reared in a separate cylindrical glass cage (16 cm in height and 5 cm in diameter). Because egg cannibalism is observed in coccinellids when there is low density of prey (9), beetles were supplied daily with an abundance of *A. nerii* scales of all stages in order to avoid egg cannibalism by adults. The number of eggs per oviposition as well as the total number of eggs in each cage, were counted once a day.

Statistical analysis In order to compare prey consumption and longevity between males and females, as well as longevity between mated and unmated females, the data were tested for significance using analysis of variance (ANOVA) and the means were separated by Student's t-test (12).

RESULTS

Prey consumption by larvae The average daily prey consumption during each larval stage, as well as the duration of larval development, are shown in Figure 1. An increase in prey consumption was observed during the second day in each stage, followed by a decrease during the following days. Both daily prey consumption range and total prey consumption of each larval stage are presented in Table 1.

TABLE 1. Daily and total prey consumption of *Rhyzobius lophanthae* larvae

Larval stage	N	Prey consumption (number of *Aspidiotus nerii* adult females)				
		Daily		Total		
		min	max	min	max	average ±SD
1st	25	0	1.5	0.5	2	1.2±0.38
2nd	25	0.5	2	2	4	2.7±0.69
3rd	25	0.5	5	5	10	7.5±1.80
4th	25	0	10	20	30	24.6±3.10
Total development (from egg to pupa)				32	44	36.0±2.86

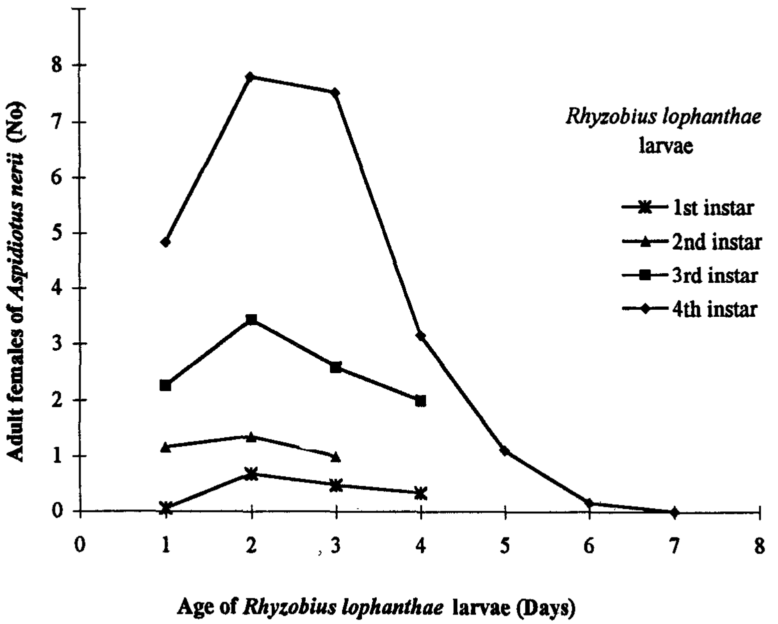

Fig. 1. Average daily food consumption (adult females of *Aspidiotus nerii*) of *Rhyzobius lophanthae* larvae. Duration of larval development, in days (mean±SD): 1st instar, 3±0.45; 2nd instar, 2.2±0.37; 3rd instar, 2.7±0.61; 4th instar: 6.2±0.50.

Prey consumption by adults The average prey consumption by *R. lophanthae* adults during their lifetime is shown in Figure 2. An increase in the average daily prey consumption during the first and second 10-day periods was followed by a decrease during the fourth and fifth periods. After the sixth 10-day period, prey consumption decreased progressively. The daily prey consumption range and the total prey consumption by adults are presented in Table 2. Females consumed significantly more ($t=2.35$, $P<0.05$) prey than males throughout their entire life, although the longevity of females (mean±SD, 119.4±25.4 days) was not significantly different ($t=0.17$, $P<0.05$) from that of males (123.3±38.7 days).

TABLE 2. Daily and total prey consumption of *Rhyzobius lophanthae* adults

Sex	N	Prey consumption (number of *Aspidiotus nerii* adult females)				
		Daily		Total		
		min	max	min	max	average ±SD
Males	12	0	7	132	501	390.6±103.3
Females	13	0	12	334	800	672.3±121.3

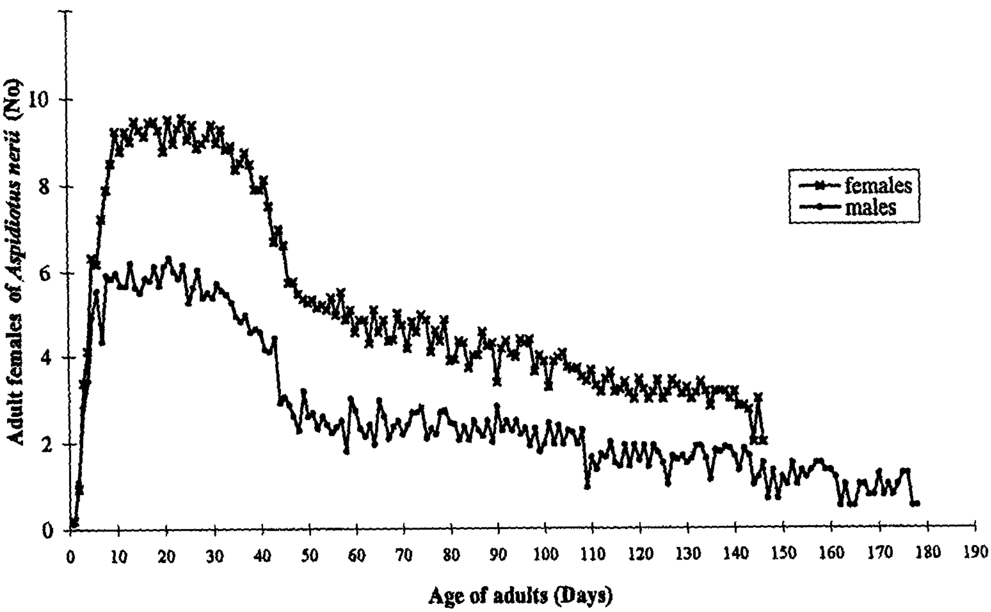

Fig. 2. Average daily food consumption (number of adult females of *Aspidiotus nerii*) by *Rhyzobius lophanthae* adults (12 adults and 13 females).

Egg laying Eggs of *R. lophanthae* were found mainly under *A. nerii* covers (98.3% of the total of 15,842 eggs). Some others were found on the upper surface of scale covers, on potato sprouts and on the cage surfaces. The eggs found under the scale covers were single or in groups of 2, 3, 4 or 5. More than one-third of the eggs (36.9%) which were oviposited under the scale covers, were found in groups of three; the percentage of eggs found in groups of 2, 4, 1 and 5 decreased progressively (Fig. 3). All the eggs found on the upper surface of *A. nerii* scale covers, on potato sprouts and on the cage surface, were oviposited singly.

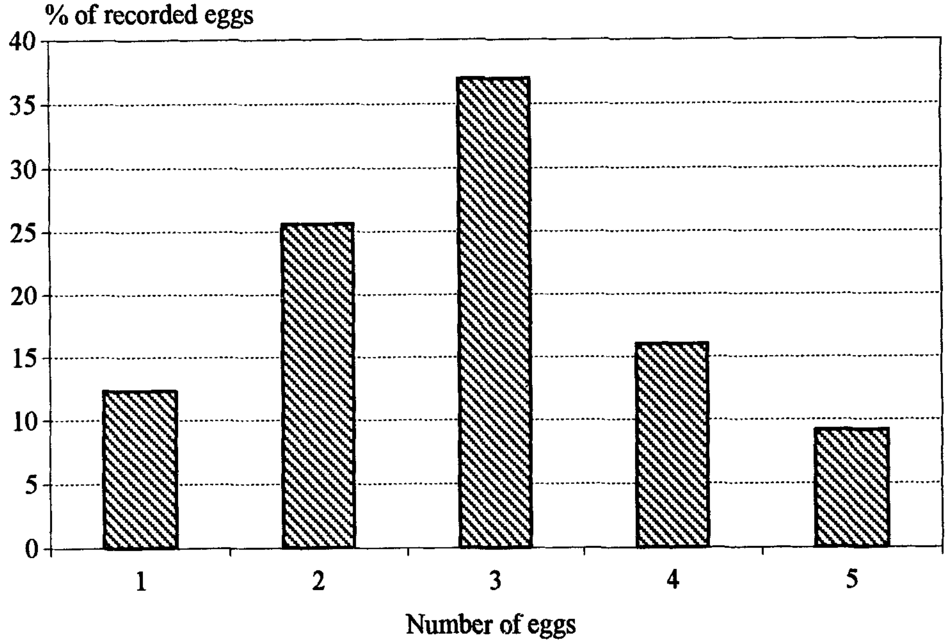

Fig. 3. Percentage of eggs recorded singly, or in groups of 2, 3, 4, and 5 eggs (total number of eggs = 15,842).

Daily fecundity The average daily fecundity, as shown in Figure 4, increased during the first and second 10-day periods and reached the highest values during the third 10-day period. A marked decrease in egg laying was observed during the fourth and fifth 10-day periods, followed by a lesser one subsequently. The maximum daily fecundity of the females fluctuated between 18 and 25 eggs, and was recorded in 23 females between the second and fourth 10-day periods after their emergence (day 17 – day 34), and in two females during the first period (day 9 and day 10). Females continued to oviposit throughout their entire life, which lasted 63.4±19.8 days. Half of the tested females ceased oviposition 2.85±2.41 days before their death.

Total fecundity The total fecundity of *R. lophanthae* females ranged from 222 to 1152 eggs. After grading the total fecundity in classes of 100 eggs, it was found that 32% of the tested females belonged to the 600–700-egg group. The average fecundity of 25 *R. lophanthae* females was 633.7±1.99.7 (mean±SD) eggs per female.

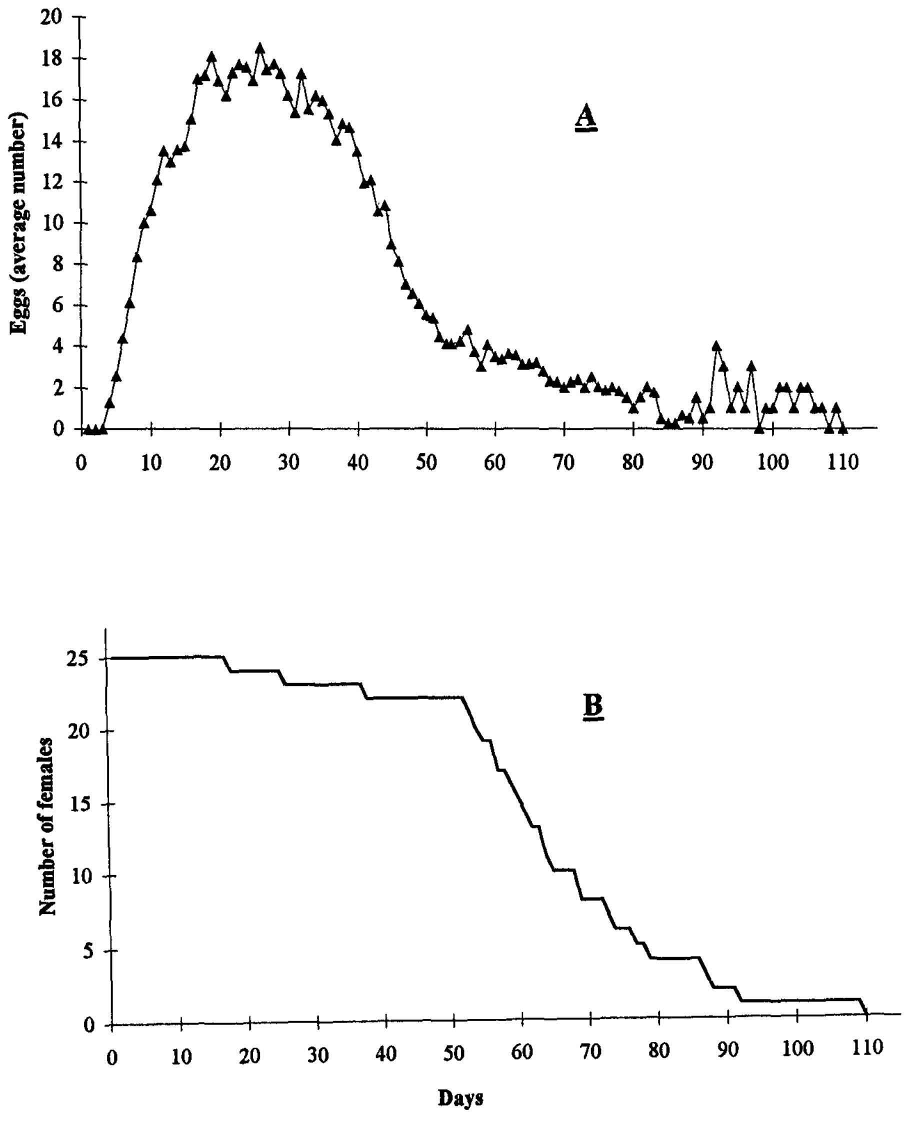

Fig. 4. Average daily fecundity *(A)* and survival *(B)* of 25 *Rhyzobius lophanthae* females.

DISCUSSION

Prey consumption by larvae The increase in prey consumption which was observed during the second day of all larval instars, could be explained by the increased metabolic requirements due to the larval growth during each instar. The reduction in prey consumption which was observed during the last days of all larval instars, could be attributed to the decreasing need for prey, due to the coming molting. This period of decreasing prey consumption lasted longer in the 4th instar (from day 3 to day 5). A similar rise and fall in prey consumption during a larval instar is reported also for other species (3,8,23,25,26). Data on the quantity of prey consumption are given in other studies (6), but they are expressed in weight and not in numbers of adult *A. nerii*. Cividanes and Gutierrez (6), by rearing larvae in groups of five individuals, estimated that 6.83 mg dry weight of scale (*A. nerii*) is consumed to produce 1 mg dry weight of *R. lophanthae* larva.

Prey consumption by adults The intense feeding activity of adults which was observed between the first and fifth 10-day periods after their emergence (Fig. 2), could be attributed to the corresponding intense reproductive activity (Fig. 4) during the same period. The great feeding activity of females (compared to males) during their lifetime, which was noted in *R. lophanthae* in this study, is observed also in other coccinellid predators. Hodeck reports that ovipositing females in particular consume more than males (9). The average daily prey consumption of *C. bipustulatus*, when reared on the diaspidid *Chrysomphalus aonidum* (Linnaeus), was found to be 4.1 scales for males and 6.1 for females (27).

In order to determine the daily prey consumption of adults, Cividanes and Gutierrez (6) formulated a metabolic pool model for the development of *R. lophanthae*. With this tool it was determined that an average rate of 8.5 *A. nerii* consumed by a female predator per day, corresponds to a rate of 20 deposited eggs/day. Similar rates of prey consumption (8.9 *A. nerii* adults) and fecundity (16.3 eggs/day) were observed in the present study for the second to fourth 10-day periods, although these values could not be absolutely correlated, since prey consumption was studied on virgin females and fecundity on mated females. Marin (14), using as prey *P. aspidistrae* (Signoret) (Homoptera: Diaspididae), found that *R. lophanthae* females consumed 12 scales/day, whereas consumption by males was approximately one-third of that value. This different rate of prey consumption of *R. lophanthae* adults reared on *P. aspidistrae* (14) and on *A. nerii* (Fig. 2) could be attributed to the differences between the host scales. According to Honda and Luck (10), the amount of scales consumed by *R. lophanthae* is related to the morphological construction of the host scale's cover and body. The fact that the kind of prey influences the amount of prey consumed by a predator is commonplace also among other species of coccinellids (9).

Egg laying Most of the eggs (98.3%) of *R. lophanthae* in the present study were found under *A. nerii* scale covers, in groups of one to five eggs (Fig. 3). Eggs of *R. lophanthae* have been observed in similar clusters in nature (22), under penetrated scale covers, in parasitoids' exit holes and under male scale covers of *Chrysomphalus dictyospermi* (Morgan), *Parlatoria zizyphi* (Lucas) and *Lepidosaphes beckii* (Newman) (Homoptera: Diaspididae). These eggs were laid mostly in groups of one to five (22). Eggs of other species of coccoidophagous coccinellids were also found in nature in small clusters under scale covers and in other protected sites (17). This way of ovipositing is probably related to the protection of eggs from natural enemies and/or cannibalism.

Total fecundity *R. lophanthae*, reared and fed on *Chrysomphalus ficus* Ashmead (Homoptera: Diaspididae), laid during its lifetime 600–700 eggs, with a maximum of 1200 eggs (21). Despite the use of a different host scale, these numbers are similar to those recorded in the present study. Furthermore, Rubstov (18) reports that *R. lophanthae* fed on diaspidid scales has an average fecundity of 500 eggs, with a maximum of 800 or more. Fecundity of more than 600 eggs per female is considered to be high for coccoidophagous predators (17). The total fecundity of coccoidophagous coccinellids is 529 eggs per female for *C. bipustulatus* (24), 228–351 for *C. nigritus* and 186 for *S. pakistanensis*; the total fecundity of the coccoidophagous nitidulid *C. semiflavus* is 34 eggs per female (1).

Adult longevity The average longevity (mean ± SD) of the *R. lophanthae* virgin adults which were reared in the study of prey consumption (males: 123.3±38.7 days, females: 119.4±25.4 days) was significantly longer (t=7.7, $P<0.05$) than that of the mated females in the study of fecundity (63.4±19.8 days). This difference could be explained by the mating activity. The fact that matings influence adult longevity and fecundity has been reported for various species of insects. Quiring and McNeil (16) found that unmated females of *Agromyza frontella* (Rondani) (Diptera: Agromyzidae) live longer than mated females. The same is true for *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) (13). However, in *Trioxys (Binodoxys) indicus* Subba Rao and Sharma (Hymenoptera: Aphidiidae), the longevity of mated females is longer than that of unmated (15). Danthanarayana and Gu (7) found that mating does not affect the longevity of the female *Epiphyas postvittana* (Walker) (Lepidoptera: Tortricidae), and that the number of eggs laid by mated females of this species was double that laid by unmated ones.

The total prey consumption of *R. lophanthae*, from the 1st larval instar until the death of the adult (426.6 *A. nerii* scales by males, 708.3 by females, Tables 1 and 2) and the predator's high fecundity, could partly explain its effectiveness as a natural enemy of diaspidids. It is easy to mass rear *R. lophanthae* in the insectary, due to the facility with which *A. nerii* can be reared on potato tubers and sprouts. Augmentative releases of *R. lophanthae* in nature could be effective in controlling diaspidids, especially during summer months, when the population of other coccinellids (*C. bipustulatus*) suffers due to increasing parasitism on its larvae (11). The results of this study could be useful for the evaluation of *R. lophanthae* as a biocontrol agent, since data on *e.g.* prey consumption, fecundity and longevity are used in indirect methods, such as the graphic methods, to study the effectiveness of Coccinellidae (9). Van Emden [in Hodek (9)], using the prey consumption of predators in a system of three axes, expressed graphically their efficiency against aphid populations in the field.

ACKNOWLEDGMENTS

The author would like to express his gratitude to Dr. P. Katsoyannos, Head of the Laboratory of Biological Control of the Benaki Phytopathological Institute, for his helpful advice during the course of this study.

REFERENCES

1. Ahmad, R. (1970) Studies in West Pakistan on the biology of one Nitidulid species and two Coccinellid species (Coleoptera) that attack scale insects (Hom., Coccoidea). *Bull. Entomol. Res.* 60:5-16.
2. Argyriou, L.C. and Katsoyannos, P. (1977) Coccinellidae species found in the olive groves of Greece. *Ann. Inst. Phytopathol. Benaki* (N.S.) 11:331-345.
3. Beenakkers, A.M.T., Meisen, M.A.H.Q. and Scheres, J.M.J.C. (1971) Influence of temperature and food on growth and digestion in fifth instar larvae and adults of *Locusta*. *J. Insect Physiol.* 17:871-880.
4. Bennet, F.D. and Hughes, I.W. (1959) Biological control of insect pests in Bermuda. *Bull. Entomol. Res.* 50:424-428.
5. Bouvier, E.L. (1913) Coccinelles contre Cochenilles. *Rev. Sci. Paris* 20:673-677.

6. Cividanes, F.J. and Gutierrez, A.P. (1996) Modeling the age-specific per capita growth and reproduction of *R. lophanthae* (Col.: Coccinellidae). *Entomophaga* 41:257-266.
7. Danthanarayana, W. and Gu, H. (1991) Multiple mating and its effect on the reproductive success of female *Epiphyas postvittana* (Lepidoptera: Tortricidae). *Ecol. Entomol.* 16:169-175.
8. Hill, L. and Goldsworthy, G.J. (1968) Growth, feeding activity, and the utilisation of reserves in larvae of *Locusta. J. Insect Physiol.* 14:1085-1098.
9. Hodek, I. (1973) Biology of Coccinellidae. Czechoslovak Academy of Sciences, Prague, Czechoslovakia.
10. Honda, J.Y. and Luck, R.F. (1995) Scale morphology effects on feeding behavior and biological control potential of *Rhyzobius lophanthae* (Coleoptera: Coccinellidae). *Ann. Entomol. Soc. Am.* 88:441-450.
11. Katsoyannos, P. (1996) Integrated Insect Pest Management for Citrus in Northern Mediterranean Countries. Benaki Phytopathological Institute, Kifissia, Athens, Greece.
12. Landi, R. (1977) Lezioni di Metodologia e Tecnica Sperimentale. Cedam, Padova, Italy.
13. Lingren, P.D., Warner, W.B. and Henneberry, T.J. (1988) Influence of Delayed Mating on Egg Production, Egg Viability, Mating, and Longevity of Female Pink Bollworm (Lepidoptera: Gelechiidae). *Environ. Entomol.* 17:86-89.
14. Marin, R. (1983) Biologia y capacidad de predación de *Lindorus lophanthae* (Blais.) (Col.: Coccinellidae) predator de *Pinaspis aspidistrae* (Sign.) (Hom.: Diaspididae). *Rev. Peru. Entomol.* 26:63-66.
15. Pandey, R.K., Singh, R. and Tripathi, C.P.M. (1984) Bionomics of *Trioxys (Binodoxus) indicus*, an aphidiid parasitoid of *Aphis craccivora. J. Appl. Entomol.* 98:113-118.
16. Quiring, D.T. and McNeil, J.N. (1984) Influence of intraspecific larval competition and mating on the longevity and reproductive performance of females of the leaf miner *Agromyza frontella* (Rondani) (Diptera: Agromyzidae). *Can. J. Zool.* 62:2197-2200.
17. Rosen, D. (1990) Armored Scale Insects, Their Biology, Natural Enemies and Control. Vol. B. Elsevier, New York, NY.
18. Rubstov, I.A. (1952) *Lindorus* – an effective predator of diaspine scales. *Entomol. Obozr.* 32:96-106.
19. Rungs, C. (1950) Sur l'extension spontanée au Maroc du *Rhyzobius (Lindorus) lophanthae* Blaisd. (Col.: Coccinellidae). *Bull. Soc. Entomol. Fr.* 55(1):9-11.
20. Salvadores, A.Z. (1913) El Duranzo (The Peach). Reprint from Bol. Minist. Agric. Buenos Aires (in *Rev. Appl. Entomol.* 1914) II.
21. Sezer, S. (1969) Etude morphologique, biologique et écologique de: *Lindorus lophanthae* Blaisdell et *Scymnus (S.) apetri* Mulsant (Coleoptera: Coccinellidae). Thèse presentée à la Faculté de Sciences de l'Université de Paris.
22. Smirnoff, W. (1950) Sur la biologie au Maroc de *Rhyzobius (Lindorus) lophanthae* Blaisd. (Col. Coccinellidae). *Rev. Pathol. Veg. Entomol. Agric. Fr.* XXIX(4):190-194.
23. Tobe, S.S. and Loughton, B.G. (1969) An investigation of haemolymph protein economy during the fifth instar of *Locusta migratoria migratorioides. J. Insect Physiol.* 15:1659-1672.
24. Uygun, N. and Elekcioglou, N.Z. (1998) Effect of three diaspididae prey species on development and fecundity of the lady beetle *Chilocorus bipustulatus* in the laboratory. *BioControl* 43:153-162.
25. Woodring, J.P., Roe, R.M. and Clifford, C.W. (1977) Relation of feeding, growth and metabolism to age in the larval, female house cricket. *J. Insect Physiol.* 23:207-212.
26. Woodring, J.P. (1983) Control of moulting in the house cricket, *Acheta domesticus. J. Insect Physiol.* 29:461-464.
27. Yinon, U. (1973) Food consumption of the armored scale lady-beetle *Chilocorus bipustulatus* (Coccinellidae). *Entomol. Exp. Appl.* 12:139-146.
28. Yus, R. (1973) On the presence in the Iberian Peninsula of *Rhizobius lophanthae* (Blaisdell, 1892) (Col. Coccinellidae). *Graellsia* 29:111-115.