doi:10.14720/aas.2019.113.1.07 Original research article / izvirni znanstveni članek

Bionomics of *Chilocorus infernalis* Mulsant, 1853 (Coleoptera: Coccinellidae), a predator of San Jose scale, *Diaspidiotus perniciosus* (Comstock, 1881) under laboratory conditions

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Received July 23, 2018; accepted January 03, 2019.
Delo je prispelo 23. julija 2018, sprejeto 03. januarja 2019.

ABSTRACT

The bionomics of *Chilocorus infernalis* Mulsant, 1853, a natural enemy of San Jose scale, was studied under laboratory conditions (26 ± 2˚C, and 65 ± 5% relative humidity). The eggs were deposited in groups and on average 45.68 ± 24.70 eggs were laid by female. Mean observed incubation period was 6.33 ± 1.52 days. Four instar grubs were observed, and mean duration of all four grubs was found to be 19.98 days. The pupal stage lasted for 8.00 ± 0.50 days and after adults emerged out.

Key words: bionomics; natural enemies; San Jose scale; incubation period; larval instars

IZVLEČEK

BIONOMIJA VRSTE *Chilocorus infernalis* Mulsant, 1853 (Coleoptera: Coccinellidae), PLENILCA AMERIŠKEGA KAPARJA (*Diaspidiotus perniciosus* (Comstock, 1881)) V LABORATORIJSKIH RAZMERAH

Bionomija vrste *Chilocorus infernalis* Mulsant, 1853, naravnega sovražnika ameriškega kaparja, je bila preučevana v laboratorijskih razmerah (26 ± 2˚C in 65 ± 5 % relativne zračne vlažnosti). Samice plenilca so jajčeca odlagale v skupinah, v poprečju 45,68 ± 24,70 jajčec na samico. V povprečju so se ličinke razvile iz jajčec v 6,33 ± 1,52 dneh. Ugotovljene so bile štiri larvalne stopnje, katerih povprečna življenska doba je bila 19,98 dni. Razvojni štadij bube je trajal 8,00 ± 0,50 dni, nakar so se izlegli imagi.

Ključne besede: bionomija; naravni sovražniki; ameriški kapar; inkubacijska doba; stopnje ličink

1 INTRODUCTION

Coccinellidae is the largest family of order Coleoptera commonly known as ladybird beetles or lady bugs which are recognized for their predacious nature. They are important group of beetles from both economic point of view as their use in biological control and in their diversity and adaptation to a number of differing habitats. They play important role in regulating insect pests, especially aphids, leafhoppers, scale insects, mealy bugs, mites and softbodied insects (Slipinski, 2007). Among the six sub families of Coccinellidae, sub family Chilocorinae is one of the most important as it is the predator of scale insects. The latter are sap feeding insects named for the scale or shell like waxy covering their bodies. They possess piercing-sucking type of mouth parts. Depending upon species, scale insects may be found on plant stems, twigs, trunks or fruits. Sap feeding by scale insects cause yellowing or wilting of leaves, stunting or unthrifty appearance of the plants, and eventually death of all or part of the plant when infestations are heavy.

San Jose scale, *Diaspidiotus perniciosus* (Comstock, 1881) is one of the recognized pests of fruit crop in Kashmir. The reddish round spots appear on fruit as a result of infestation due to scales; this not only gives it bad shape but also reduces its market value. They also affect general vigour of plant and terminal twigs usually die (Masoodi & Trali, 1987). The incidences of the pest vary from year to year and from area to area because of changes in the factors influencing their population dynamics and dispersal (Sofi, 2006). *Chilocorus infernalis* Mulsant, 1853 was introduced in swat for the

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control of *D. perniciosus* on apples, resulting in reduction of pest populations (Mohyuddin, 1982). Both adults and larvae of *C. infernalis* were found feeding on San Jose scale (Rahman et al., 1961). It is the most beneficial beetle against scale pests as its mature and immature stages are voracious feeders. Thus this beetle plays important role as biocontrol for those crops that are especially susceptible to scales. The present study was therefore, carried out to gather relevant information with particular reference to biology of *C. infernalis*, the predator of scales.

2 MATERIALS AND METHODS

The experiment was conducted in the Entomology laboratory of department of Zoology, University of Kashmir under controlled conditions (26 ± 2˚C and 65 ± 5% relative humidity). The present study was done during two years (2014 to 2015). Adults of *C. infernalis* were collected from apple orchards and brought to the laboratory. Three mating pairs were kept in glass jars (15 × 5 cm) covered with muslin cloth. They were provided with abundant supply of food in the form of infested twigs of San Jose scale, *Diaspidiotus perniciosus* until oviposition. Dry twigs were replaced with fresh ones after every 24 hours in order to avoid contamination. The glass jars were also provided with crumpled paper to act as oviposition site. The eggs laid on crumpled paper and on walls of glass jars were removed using camel hair brush. They were counted and transferred in Petri dishes (12 cm in diameter). In order to maintain humidity moist filter paper was placed at bottom of Petri dishes. The filter paper was replaced daily to avoid contamination untill hatching. Observations were recorded carefully. The newly hatched first instar grubs were placed gently with the help of camel hair brush and transferred individually in Petri dishes. They were also provided with food (scales). Larval duration of each instar was recorded after moulting and different larval instars were separated from each other by head capsule measurement (Dyar, 1890). Measurement of head capsule was done with the help of digital vernier calliper. Duration of each larval instar was also observed and recorded carefully.

Newly emerged adults were placed in separate glass jars in pairs to observe the mating behaviour, duration of mating, oviposition and adult's longevity. The whole experiment was replicated 3 times.

Arithmetic mean, range, standard error (SE) and standard deviation (SD) were used to present the obtained data. Head width of different larval instars was used to calculate total larval instars by Dyar's ratio. Statistical analysis was done by using SPSS (Version 16.00).

3 RESULTS AND DISCUSSION

The life history of *C. infernalis* includes following life stages:

3.1 Egg stage

The eggs are evenly rounded; yellow in colour and cylindrical in shape at both ends. Eggs are laid in groups on the surface of leaf. On average, 42 eggs are laid in batches. The eggs are about 1.22 mm in length and 0.25 mm in breadth (Table 1).

Table 1: Measurement of egg of *Chilocorus infernalis*

Variable	N	Mean ± SD	Minimum	Maximum
Egg Length (mm)	10	1.22 ± 0.17	1.00	1.44
Egg Breadth (mm)	10	0.25 ± 0.06	0.19	0.35

N = Number of observations

3.2 Larval stages

Before hatching, the grub is visible through the egg shell as a coiled mass. Body covered with prominent senti on dorsum. Prothorax possesses five pairs of senti while mesothorax possesses four pairs. Larval instars are black in colour. 1st, 2nd, 3rd and 4th larval instars are differentiated on the basis of head width (Dyar's rule). Table 2 gives us mean length of 1st, 2nd, 3rd and 4th instars. Mean duration of 1st instar was 4.00 days, 4.3 days for 2nd instar, 5.00 days for 3rd instar and 6.00 for 4th instar (Table 3).

Table 2: Comparison of observed (mean) and expected values of head capsule widths (mm) of the grub of *Chilocorus infernalis*

Larval Instars	Head capsule width (mm)			Difference (mm)
	Observed (Mean ± SE)	Range	Expected[a]	
I	0.30 ± 0.33	0.10-0.35	0.30	0.00
II	0.50 ± 0.34	0.35-0.63	0.48	0.02
III	0.78 ± 0.01	0.63-0.85	0.8	0.02
IV	0.86 ± 0.00	0.85-0.88	1.2	0. 34

[a]Expected head capsule width established by Dyar's ratio (1.6 mm). Multiplying Dyar's ratio with the observed head capsule width of 1st instar grub gives the expected head capsule width of 2nd instar which when multiplied again with Dyar's ratio gives expected head capsule width of 3rd instar and so on.

Mean observed head capsule width of 1st instar grub (N = 10) = 0.30 mm
Mean observed head capsule width of 2nd instar grub (N = 10) = 0.50 mm

$$\text{Growth ratio (Dyar's ratio)} = \frac{\text{Head capsule width of 2nd instar grub}}{\text{Head capsule width of 1st instar grub}}$$

= 0.50/0.30
= 1.6 mm

Table 3: Duration of immature stages of *Chilocorus infernalis*

Developmental stage	Observations			Mean ± SD
	1	2	3	
1st instar grub	3.5 days	4 days	4.5 days	4.00 ± 0.50
2nd instar grub	5 days	4.5 days	3.5 days	4.33 ± 0.77
3rd instar grub	6 days	5.5 days	4 days	5.00 ± 1.32
4th instar grub	7.5 days	5.0 days	5.5 days	6.00 ± 1.32
Total grub period				19.33

3.3 Pupa

The pupa is formed within the shed larval skin. Pupa is somewhat triangular in shape with light brown in colour just after pupation and gradually changes into deep brown and black. Only extreme posterior parts are visible from upper side and eight abdominal segments are also visible dorsally. Wing pads are meeting on ventral side. Pronotum is emarginated and laterally prolonged for reception of head. Lateral marginals are rounded. The pupal period was observed to take 6.0 - 8 days. Pupal length ranged between 3.97 and 5.01 mm, whereas breadth ranged between 2.72 –and 3.02 mm.

3.4 Adult

Adults are sub hemispherical and very moderately compressed. Head is black deeply inserted and not visible from above. Pronotum is deeply black. Scutellum is clearly visible, black and having shiny lusture. Elytra were black in color with a pair of reddish spots on each. Both spots are present in a transverse line. Females are generally larger in size as compared to males. Mean length of adult was 5.15 mm and breadth was 4.32 mm (Table 4).

Table 4: Measurement of adult of *Chilocorus infernalis*

Variable	N	Mean ± SD	Minimum	Maximum
Adult Length (mm)	10	5.15 ± 0.25	4.72	5.50
Adult Breadth (mm)	10	4.32 ± 0.08	4.20	4.43

N = Number of observations

Table 5 and Fig.1 depicts the mean of three observations of different developmental stages of *C. infernalis*.

Table 5: Developmental duration (in days) of different life stages of *Chilocorus infernalis*

Parameter	Observations			Mean ± SD
	A	B	C	
Mating period (in minutes)	65	40	30	45.00 ± 18.02
Oviposition (in days)	22	20	14	18.68 ± 4.16
Fecundity (eggs in batch)	72	42	23	45.68 ± 24.70
Incubation period (in days)	8	6	5	6.33 ± 1.52
1st instar (in days)	4.5	4	3.5	4.00 ± 0.50
2nd instar (in days)	5	4.5	3.5	4.33 ± 0.77
3rd instar (in days)	6	5.5	4	5.00 ± 1.32
4th instar (in days)	7.5	5	5.5	6.00 ± 1.32
Prepupal period (in days)	3	2	2	2.33 ± 0.57
Pupal period (in days)	8.5	8	7.5	8.00 ± 0.50
Male longevity (in days)	45	43	40	42.68 ± 2.51
Female longevity (in days)	80	76	53	69.68 ±14.58

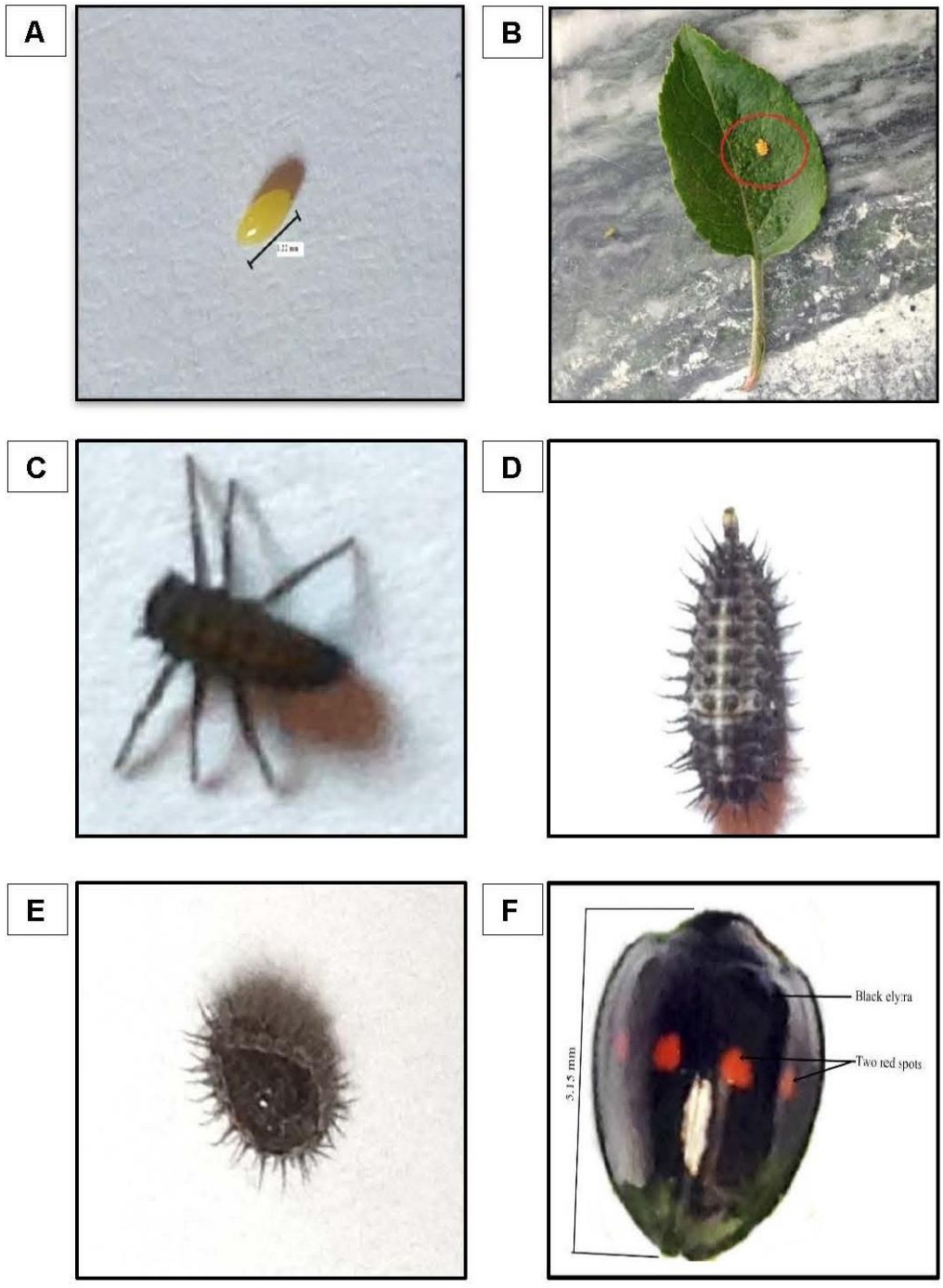

Figure 1: Different developmental stages of *Chilocorus infernalis*. (A) Egg of *C. infernalis*. (B) Eggs laid on leaf surface. (C) First instar grub. (D) Fourth instar grub. (E) Pupa. (F) Adult.

During the present study *C. infernalis* was found as a dominating species in fruit ecosystem and wild vegetation due to availability of prey, but it was found absent in vegetable ecosystem in a previous study conducted by Rasheed & Buhroo (2018). Buhroo et al. (2000) found that the common ladybird beetle, *C. bijugus* was effective and predominant predator of San Jose scale which passed three generations along with its host. It was also observed that the development of this predator corresponded to the development of San Jose scale and has got well established in the orchard ecosystem. Furthermore, Thakur et al. (1989) conducted extensive field surveys in India and their study revealed that four species of parasitoids and three species of

predators, *Chilocorus bijugus,* Mulsant 1856, *Coccinella septempunctata* (Linnaeus, 1758), *Sticholotis marginalis* Kapur, 1956 were among the effective natural enemies of *D. perniciosus* Comstock, 1881 in Jammu and Kashmir. Ahmad et al. (1999) studied the spatial distribution and phenology of adult coccinellid *C. infernalis* at two localities on 8-10 year-old apple orchards at high altitudes (1500-1700 meter above sea level) of Kashmir. The results showed that adult *C. infernalis* was the most common species than the *Coccinella septempunctata*; *Exochomus flavipes* (Thunberg, 1781) and three unidentified species which were very few in numbers. Khan (2010) studied exploitation of *C. infernalis* for suppression of the San Jose scale in apple orchards at five locations of Kashmir. The results revealed that the release of 35 individuals of *C. infernalis* / plant reduced significantly the infestation of the San Jose scale in all locations of Kashmir.

Rawat et al. (1992) studied the biology of *C. bijugus* Mulsant, a predator of San Jose scale. The results revealed that mean length of egg is 0.93 mm and mean breadth 0.46 mm. Whereas incubation period ranged from 3 to 6 days (Mean = 4.8). However these findings are not in agreement with present study. Kapur (1954) reported incubation period as 3.44 days without mentioning the temperature at which the study was made, whereas Jalali and Singh (1989) reported it as 6.0 to 6.8 days on different host insects at 27 ± 1.8 °C and 55 ± 2.3 % relative humidity. These are close observations with present study. However, these findings are not in agreement with those reported by Chanyuvadze (1976) (8 to 9 days) and Murashevskaya (1969) (8-9 days) for *Chilocorus renipustulatus*. These differences in the incubation periods may be attributed to variations in ambient temperature and relative humidity.

Ahmad and Ghani (1966) reported total grub period of 21.0 days which are in fair agreement to our findings, but differ from Rawat et al. (1992) and Gupta and Inderjit (2007) which showed total grub period of 25 to 40 days (average 31.9 days) and 12 to 16 days respectively.

Rawat et al. (1992) showed mean length of pupa was 5.75 mm (range 5.10 to 6.50) and the average breadth 3.70 mm (range 3.50 to 4.20). The pupal duration varied from 11 to 16 days with an average of 12.62 days. These results however do not agree with the findings of present study. Our observations corroborate with those of Chanyuvadze (1976) who reported 11 days in case of *C. bijugus*, Kapur (1954), Ahmad and Ghani (1966) and Jalali and Singh (1989) who reported the pupal duration as 7.2 days, 8.0 days for *C. infernalis* and 6.1 to 8.0 days in case of *C. bijugus* respectively.

Rawat et al. (1992) reported the oviposition period varied from 8 to 16 (average 11.6 ± 0.48) days under laboratory conditions. The female on an average produced 100.7 ± 1.44 (range 60 to 135) eggs. However during present study oviposition period was found varied between 14 to 22 (average 18.68 ± 4.16) days. The females on an average produced 45.68 ± 24.70 eggs (range 23 to 72). These results differ from findings of Jalali and Singh (1989) who reported that *C. bijugus* had a high fecundity of 92 on *D. perniciosus* and Ahmad and Ghani (1966), Ahmad (1970) and Greathead and Pope (1977). These workers have reported very high fecundity (228 to 858 eggs) in case of *Chilocorus nigritus*Fabricius, 1798.

4 CONCLUSIONS

It can be concluded that the biology of *C. infernalis* under laboratory conditions showed better longevity. The eggs were deposited in groups and on average 45.68 ± 24.70 eggs were laid by female. Incubation period was 6.33 ± 1.52 days. Four instar grubs were observed and mean duration of four instars was found to be 19.98 days. The pupal stage lasted for 8.00 ± 0.50 days and after that, adults emerged out. Due to its short life cycle, it can be successfully used for mass rearing and then its establishment in pest prevalent regions. This suggests the possible role of this beetle as an efficient biological control agent. This will also decrease the application of harmful pesticides and allow these natural enemies to do their function successfully in the field.

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