



## Growth, development and feeding potential of grubs of *Chilocorus infernalis* Mulsant (Coleoptera: Coccinellidae) on the San Jose scale, *Quadraspidiotus perniciosus* (Comstock)

P. R. GUPTA andINDERJIT SINGH

Department of Entomology and Apiculture, Dr. Y. S. Parmar University of Horticulture and Forestry Nauni, Solan - 173 230, Himachal Pradesh, India

E-mail: premra\_21@yahoo.co.in

**ABSTRACT:** *Chilocorus infernalis* (Mulsant) completed egg, larval, prepupal and pupal development in 7-8, 12-16, 1-3 and 7-10 days, respectively, on the San Jose scale, *Quadraspidiotus perniciosus* (Comstock) and required 27-37 (mean 32.8) days for adult formation with 64 per cent survival till adult stage at temperature regime of 16.5-32 °C and 52-79 per cent relative humidity. The four larval instars, identified on the basis of width of the head capsule and body length and breadth, required 675-786 (average 732), 514-637 (563) and 183-252 (217) scale insects of I, II and III (adult) instar, respectively, and fourth instar grubs consumed 56.1 per cent of the total requirement. In mixed population of the scale insect, mean consumption by four consecutive larval instars was 26, 38, 56 and 120 scale insects with a mean consumption of 8.7, 12.6, 18.8 and 24.2 scales per day per grub; the overall larval requirement was 155-328 (average 240) scale insects. While III and IV instar grub preferred adult females, the I and II instar grub showed preference for II instar (female).

**KEY WORDS:** *Chilocorus infernalis*, development, predatory potential, *Quadraspidiotus perniciosus*

### INTRODUCTION

*Chilocorus* is a well-documented coccinellid genus and recognized as an important diaspine predator throughout the world. From India, 6 species were reported (Nagaraja and Hussainy, 1967) and amongst these, *Chilocorus infernalis* Mulsant (earlier referred to as *Chilocorus bijugus*) is an effective predator of the San Jose scale, *Quadraspidiotus perniciosus* (Comstock) (Rawat *et al.*, 1988; Thakur *et al.*, 1989; Gupta, 2005). Thakur and Gupta (1997) also reported it to predate voraciously upon olive white coccid *Metacaronema japonica* Maskell at Solan. There is divergence in observation on consumption of the San Jose scale by the beetle and its larvae. While Pruthi and Rao (1951) observed an average consumption of 217 scale insects per beetle in a day, daily consumption of female scales was 65, 80 and 67 as recorded by Ahmad and Ghani (1966), Rawat *et al.* (1988) and Jalali and Singh (1989),

respectively. However, Gupta and Singh (1996) reported that *C. infernalis* could enter reproductive diapause even during summers when its average daily consumption of the San Jose scale was low (9-10 scales/beetle of either sex). The daily feeding rate per grub as reported by Jalali and Singh (1989) is 20.3-35.5 scale insects of various species, with maximum preference for the San Jose scale. The present study was, therefore, carried out to record the growth and development of the beetle to the adult stage and to determine the predatory potential of different larval instars.

### MATERIALS AND METHODS

Culture of the San Jose scale was raised on pumpkin (*Cucurbita moschata* Duch.) in the laboratory. Healthy and ripened pumpkins were cleaned, surface sterilized with cotton soaked in formaldehyde (5%) solution and thoroughly dried until free from

formaldehyde fumes. Crawlers of the San Jose scale were brushed from apple twigs/infested pumpkin and allowed to settle and grow to specific age and stage before providing them to grubs as food. Culture of *Chilocorus infernalis* was raised from the progeny of a pair of beetles on the San Jose scale. Mated females were released individually under plastic cage (2 cm diam, 3 cm ht) covered by muslin cloth and secured at its position by adhesive (Fevicol) to get eggs next day and the cage was daily changed to the new site. The scaly armature of the scale insects was carefully lifted with a fine needle to locate eggs and these were allowed to hatch *in situ* to get neonate larvae for further observation. Each neonate grub was confined under the cage or in groups of 10-15 on scale infested pumpkins. Grubs were noticed twice a day for recording the duration of the instar and mortality in each stage of the development. Exuviae of moulted insects were removed and head capsule width of each larval instar was also measured by pre-calibrated ocular micrometer under compound microscope. Besides, dimensions (length and breadth) of 10 full-fed grubs of each instar were also recorded under stereoscopic binocular microscope in order to determine the criteria for identification of instars of the grub. Regression analysis of measurements thus recorded in relation with the instars was made. Sexing of the newly emerged beetles was done as described by Gupta and Chauhan (1991) and sex ratio was worked out.

To determine the feeding potential of grubs, 20 neonates of *C. infernalis* were individually confined under plastic cage on the first instar scale insects (3-6 day old), second instar female scales (10-14 day old), III instar or adult females (19-25 day-old) and mixed population of scale insects. Each day, grubs along with their cages were shifted to a fresh unexposed site. The number of scales consumed by each grub within a day was counted by removing the scaly armature of the insect. The scaly armature of predated insect had irregular hole near the nipple and such armature was empty. Daily rate of consumption of the scale and total requirement of the grub for completion of the instar was worked out. Temperature and humidity record was maintained during the period of study. The data were subjected to appropriate statistical analysis.

## RESULTS AND DISCUSSION

### 1. Growth and development of *C. infernalis*

The incubation period of *C. infernalis* eggs was 7-8 (7.2) days with hatchability of 83.7 per cent at 20-32°

C (mean 26.2°C) and 54-70 (64) per cent relative humidity (RH). The duration of egg stage is in conformity with that of 8-9 days reported by Chanyuvadze (1976), 8-9 days observed by Ahmad and Ghani (1966) and 6-6.8 days on different scale insects as found by Jalali and Singh (1989). However, Rawat *et al.* (1992) reported incubation period of short duration (3-6 days, mean 4.8).

The grub stage of four instars was completed in 12-16 (average: 14.8 days) at 16.5-30°C (mean 24°C) and 52-69 (61) per cent RH and larval mortality was 14.1 per cent. The first three consecutive instars were completed in 3-4 days each (average 3.3, 3.2 and 3.5 days, respectively), while the fourth instar took 3-6 (5) days. The total duration of larval development was closer to 16.3 days as reported by Kapur (1954), but was of much shorter mean duration of 21 days reported by Ahmad and Ghani (1966) at 25.1°C and 70 per cent RH, 21.4 days reported by Jalali and Singh (1989) at 27±1.8°C and 55±2.3 per cent RH, 21-23 days reported by Chanyuvadze (1976) at 17-21°C and 50-60 per cent RH, and 25-40 (mean 31.9) days reported by Rawat *et al.* (1992) at 25-28°C and 65-75 per cent RH. It seems that fluctuating temperature regime of 16.5-30°C was much suited for growth and development of larvae, which can also be affected by availability of the prey and intra-specific competition. The four instars were identified on the basis of size of the head capsule and body length and breadth (across metathorax) of full-fed individual of each instar. The mean length of four consecutive instars was 1.92, 3.01, 4.34 and 6.2 mm, while body breadth was 0.73, 1.05, 1.55 and 2.57 mm, respectively. The width of head capsule was 0.319-0.392 (0.369), 0.417-0.564 (0.527), 0.662-0.809 (0.731) and 0.98-1.152 (1.065) mm, respectively. The growth of head capsule ( $Y_1$ ), and length ( $Y_2$ ) and breadth ( $Y_3$ ) of the body of larvae distinctly followed the Brooks-Dyar rule (Daly, 1985) and growth quotient calculated for these parameters was 1.42, 1.48 and 1.52, respectively, as per regression equations given below:

$$\text{Log } Y_1 = -0.586 + 0.152 X \quad (r = 0.9997)$$

$$\text{Log } Y_2 = 0.126 + 0.169 X \quad (r = 0.998)$$

$$\text{Log } Y_3 = -0.334 + 0.182 X \quad (r = 0.997),$$

where X refers to the instar (corrected to value of whole number). Thus these equations can be used to determine the instar of grub of *C. infernalis*.

The pre-pupal and the pupal stage occupied 1-3 (mean 1.9) and 7-10 (7.8) days, respectively and mortality during these stages was 3.5 and 2.2 per cent, respectively. The pupal duration falls in the range of 7-8 days as

reported by Ahmad and Ghani (1966) and Jalali and Singh (1989), but was much shorter than 11-16 (12.6) days as observed by Rawat *et al.* (1992). The total duration from egg to adult emergence was 27-37 (32.8) days and adult formation from initial lot of eggs was 64 per cent. The sex ratio, on the basis of 684 adults, was practically 1:1 (49.1% females).

## 2. Feeding potential of grubs on scale insects of specific instar

To complete the development, grubs of four consecutive instars consumed 68-87 (mean 81.7), 87-122 (99.4), 159-185 (171.5) and 328-445 (379.5) scale-insects of the first instar; 54-70 (59.9), 67-88 (72.2), 19-168 (137.7) and 226-347 (293.2) second instar female scales; and 10-16 (13.3), 13-28 (21.4), 39-54 (47.8) and 110-177 (134.2) adult female scales at temperature regime of 17-27.5 (mean 24.7) °C and 67-88 (77) per cent RH. The overall consumption of II and I instar scale insects and adult female was 675-786 (mean 732.1), 514-637 (563) and 183-252 (217), respectively (Fig.1). The mean consumption per day for these four consecutive instars comes out to be 27.2, 33.1, 57.5 and 63.4 scales of the I instar, 19.9, 24, 45.7 and 58.7 scales of the II instar, and 4.4, 7.1, 16.1 and 22.3 scales of the III instar, such that maximum feeding per day was generally on the third day of the I and II instar, second day of the II instar, and significantly higher consumption occurred in first 4 days of the IV instar (Table 1). The data on consumption of I ( $Y_I$ ) and II ( $Y_{II}$ )

instar scale insect and adult female ( $Y_{III}$ ) scales by grubs, subjected to regression analysis provided following equation:

$$\text{Log } Y_I = 1.621 + 0.224 X \quad (r = 0.968)$$

$$\text{Log } Y_{II} = 1.473 + 0.235 X \quad (r = 0.972)$$

$$\text{Log } Y_{III} = 0.725 + 0.336 X \quad (r = 0.987),$$

where Y is consumption of scales of specific instar by the grub of *C. infernalis*. Analysis of data reveals that maximum consumption of scales of any instar occurred in IV instar, which consumed 56.1 per cent of total, while III, II and I instar required 23.2, 12.1 and 9.3 per cent of the total consumption. Ahmad and Ghani (1966) found the rate of feeding of III and IV instar grubs as 14 and 34 adult scales, while in the present study, mean daily consumption was 16 and 25 scales. Jalali and Singh (1989) reported a high rate of consumption (35 adult scales/day) by grubs of unstated instar and these must be of the IV instar. As per observation of Rawat and Pawar (1993), the rate of predation of second to fourth larval instar on adult of *Q. perniciosus* is 1.8, 11.2 and 19.2 per day at 22°C and 2, 17 and 25.7 at 27°C, and grubs of the first instar do not feed on adult scales. However, the present observation reveals that even first instar grubs feed on adult scales at the rate of 4.4 scales per day; the mean daily consumption of second instar grub was quite low (about 2, as against 7.1 in the present case) in their study.

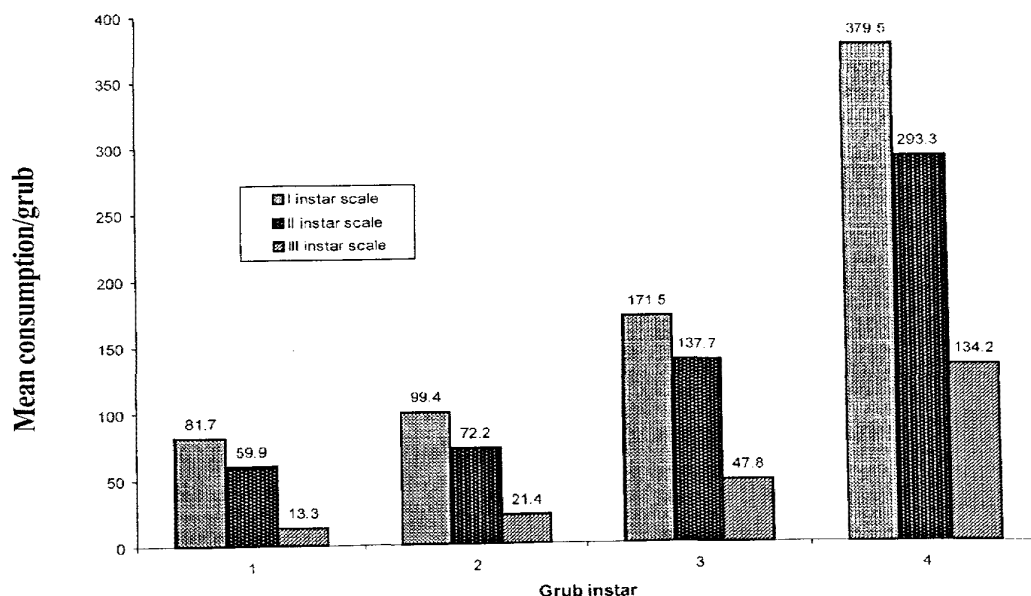


Fig.1. Mean consumption of scales by four consecutive larval instars of *C. infernalis*

**Table 1. Daily consumption of specific instar of the San Jose scale by the grub of *C. infernalis***

Grub instar of the beetle and its age	Day-wise consumption of scales of specific instar		
	I-instar	II-instar	III instar
I- instar			
1-day	22.3c	17.4c	2.8b
2-day	24.1b	18.6b	5.2a
3-day	33.3a	23.8a	5.3a
Mean	27.2	19.9	4.4
II-instar			
1-day	35.6a	24.8a	5.7b
2-day	34.8a	29.2a	8.5a
3-day	29.0a	18.0b	7.2a
Mean	33.1	24.0	7.1
III-instar			
1-day	46.0c	42.8c	15.8b
2-day	58.7b	45.0b	16.0b
3-day	64.4a	49.3a	16.4a
4-day	3.4d	-	-
Mean	57.5	45.7	16.1
IV-instar			
1-day	77.5a	58.0ab	29.3ab
2-day	80.7a	63.0a	29.5ab
3-day	82.4a	57.2ab	33.2a
4-day	76.8a	57.3ab	26.0ab
5-day	55.6b	53.7b	12.3c
6-day	7.6c	12.6c	3.7d
Mean	63.4	58.68	22.3
Overall mean	45.3	37.1	12.5

Figures in a column with same alphabet(s) under each instar do not differ significantly at  $P = 0.5$  level of significance

### 3. Feeding capacity of grubs on mixed population of the San Jose scale

During this experiment, the temperature ranged from 16.5-26.5°C (mean 24.4) and RH was 64-88 (mean 76) per cent. The first instar grubs of *C. infernalis* required on an average 26 scale insects of mixed population and showed preference for II instar females. The least preferred stage was the adult female (Table 2).

The second instar grub fed on average 38 scales and it also had preference for II instar females, followed by adult female and developing males; least preferred stage was the I instar. However, III and IV instar grubs required 56 and 120 scale insects and had maximum preference for adult female scales, followed by developing males. The male scales were also fed upon, but all instars consumed about two times more females (II and III instar) than the males (II instar onwards). The mean consumption per

**Table 2. Consumption of the San Jose scale of mixed population by grubs of *C. infernalis***

<i>C. infernalis</i> grub instar	Scale insect consumption / grub				Total consumption
	Female			Male	
	I instar	II instar	III instar (adult)	II+ pre-pupa + pupa	
I	6.0b(2-11)	12.4a (7-16)	1.3c (0-6)	6.4b (3-10)	25.9 (19-35)
II	3.3c (0-9)	15.4a (9-25)	8.3b (2-17)	10.9b (5-19)	37.9 (32-48)
III	1.5d (0-5)	11.9c (4-20)	24.3a (6-50)	18.4b (5-41)	56.2 (21-88)
IV	0.2d (0-3)	7.9c (2-18)	69.5a (38-87)	42.7b (20-62)	120.2 (83-157)

Figures in parentheses in each cell refer to range, and those in a row under the head "scale consumption / grub" with the same alphabet do not differ significantly at  $p = 0.05$  level of significance.

**Table 3. Daily consumption of San Jose scale (mixed population) by grubs of *C. infernalis***

Instar of the grub	Mean consumption at specific age (in day) of the grub					Mean Consumption per day
	1	2	3	4	5	
I	5.2b*	11.2a	9.5a	-	-	8.7
II	20.4a	15.1a	2.4b	-	-	12.6
III	22.6a	18.5ab	14.5b	-	-	18.8
IV	33.8a	34.4a	30.6a	21.4b	0.5c	24.2

\* Figures in a row followed by the same alphabet(s) do not differ significantly from each other at  $P = 0.05$  level of significance.

day per grub was 8.7, 12.6, 18.8 and 24.2 scales in four instars, which lasted for 3, 2-3, 3 and 4-5 days, respectively (Table 3). The daily consumption was higher on second and third day in I instar, first and second day in II and III instar, and during first 3-4 days of the last instar. The overall daily consumption of scale insects of mixed instar by a grub was 18.

## ACKNOWLEDGEMENTS

Authors are thankful to the Project Director, Project Directorate of Biological Control (ICAR), under A.I.C.R.P. on Biological Control, Bangalore for financial support and Professor and Head, Department of Entomology and Apiculture of the University for providing necessary facilities.

## REFERENCES

Ahmad, R. and Ghani, M. A. 1966. Biology of *Chilocorus*

*infernalis* Muls. (Coleoptera: Coccinellidae). *Technical Bulletin CIBC*, **31**: 101-106.

Chanyuvadze, H. F. 1976. Indian *Chilocorus* - a predator of diaspine scale. *Zashchita Rastenii*, **4**: 51.

Daly, H. V. 1985. Insect morphometrics. *Annual Review of Entomology*, **30**: 415-438.

Gupta, P. R. 2005. Biological control of San Jose scale in India - an overview. *Acta Horticulturae*, **696**: 427-432.

Gupta, P. R. and Chauhan, U. 1991. Sexing of the coccinellid *Chilocorus bijugus* Mulsant. *Journal of Biological Control*, **5**: 50-51.

Gupta, P. R. and Singh, I. 1996. Predation preference and reproductive performance of the coccinellid, *Chilocorus bijugus* Mulsant on the San Jose scale, pp. 75-80. In: Ambrose, D. P. (Ed.). *Biological control of Insect Pests, an Indian Scenario*. Proceedings of Symposium on

- Biological and Cultural Control of Agricultural and Medical Pests, 22-24 Feb., 1995, St. Xavier College, Palayamkottai, Tamil Nadu.
- Jalali, S. K. and Singh, S. P. 1989. Biotic potential of three coccinellid predators on various diaspine hosts. *Journal of Biological Control*, **3**: 20-23.
- Kapur, A. P. 1954. Systematic and biological notes on the ladybird beetles predacious on the San Jose scale in Kashmir with description of a new species (Coleoptera: Coccinellidae). *Records of the Indian Museum*, **52**: 254-274.
- Nagaraja, H. and Hussainy, S. U. 1967. A study of six species of *Chilocorus* (Coleoptera: Coccinellidae) predaceous on San Jose and other scale insects. *Oriental Insects*, **1**: 249-256.
- Pruthi, H. S. and Rao, V. P. 1951. *San Jose scale in India*. Bulletin No. 71, ICAR, New Delhi. 48p.
- Rawat, U. S. and Pawar, A. D. 1993. Predation potential of coccinellid, *Chilocorus bijugus* Mulsant on the San Jose scale, *Quadraspidiotus perniciosus* (Comstock) at different temperature regimes. *Journal of Advanced Zoology*, **14**: 28-32.
- Rawat, U. S., Thakur, J. N. and Pawar, A. D. 1988. Role of natural enemies in the integrated pest control of San Jose scale and woolly aphid in Himachal Pradesh, pp. 182-187. In: *Proceedings of National Symposium on Integrated Pest Control – Progress and Perspectives*, October 15-17, 1987, Trivandrum.
- Rawat, U. S., Sangal, S. K. and Pawar, A. D. 1992. Biology of *Chilocorus bijugus* Mulsant (Coleoptera: Coccinellidae), predator of San Jose scale, *Quadraspidiotus perniciosus* (Comstock). *Journal of Biological Control*, **6**: 97-100.
- Thakur, J. N., Rawat, U. S. and Pawar, A. D. 1989. Investigation on the occurrence of natural enemies of San Jose scale, *Quadraspidiotus perniciosus* Comstock (Hemiptera: Coccidae) in Jammu and Kashmir and Himachal Pradesh. *Entomon*, **14**: 143-146.
- Thakur, J. R. and Gupta, P. R. 1997. Population trend of olive white scale, *Metacaronema japonica* Maskell and its predation by *Chilocorus bijugus* Mulsant in Himachal Pradesh. *Pest Management and Economic Zoology*, **5**: 151-154.