RESEARCH ARTICLE

FEEDING POTENTIAL OF *CHRYSOPERLA ZASTROWI* SILLEMI ON SOLENOPSIS MEALY BUG, *PHENACOCCUS SOLENOPSIS* TINSLEY INFESTING COTTON

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Abstract: The feeding potential of *Chrysoperla zastrowi sillemi* (Esben-Peterson) on eggs (ovisac), nymphs and female adults of mealy bug (*Phenacoccus solenopsis*) were studied at Bio-control Laboratory, Department of Agricultural Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari during September to October 2014. In no choice feeding against cotton mealy bugs, the feeding potential of larvae of *C. zastrowi sillemi* was found more on eggs (ovisac) and nymphs than female adults (freshly formed). On eggs of mealy bug, the feeding potential of larvae of *C. zastrowi sillemi* was 1778 to 2035 (Av. 1886.60 ± 74.88) eggs with consumption rate of 177.80 to 203.50 (188.6± 7.49) eggs per day whereas on nymphs of mealy bug, it was 812 to 899 (Av. 845.50 ± 23.44) nymphs with consumption rate of 81.20 to 89.90 (Av. 84.76 ± 2.21) nymphs. When fed exclusively on female adults, it was 119 to 141 (Av. 132.15 ± 6.37) female adults with consumption rate of 13.20 to 16.90 (14.87 ±0.89) adults per day. The larvae of *C. zastrowi sillemi* developed little bit faster when fed on female adults of mealy bug than fed on eggs and nymphs. In free choice feeding of mixed stages of mealy bug, the feeding potential was found to be 886 to 998 (Av. 938.65 ± 35.09) mealy bug exhibited preference to eggs and nymphs of mealy bug more as indicated by proportion of 408 to 477 (440.90 ± 18.93) eggs, 364 to 422 (395.70 ± 15.82) nymphs and 94 to 113 (102.05 ± 4.72) female adults in mixed stages offered. The consumption rate was 88.6 to 107.2 (94.93± 5.27) mixed stages of mealy bug per day in its developmental durations of 9 to 10 (Av. 9.75 ± 0.44) days.

Keywords: *Chrysoperla zastrowi sillemi*, Feeding potential, *Phenacoccus solenopsis*

INTRODUCTION

Cotton mealy bug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) is a small, soft bodied sap sucking introduced species that cause severe damage to cotton and other field, fruit and vegetable crops (Arif *et al*., 2009; Nagrare *et al*., 2009). It was described originally from USA in 1898 (Tinsley, 1898) and regarded as an invasive pest in Asia. It was first recorded damaging cotton crop in Pakistan during 2005, since then it has become the most serious pest in Asia (Ben Dov *et al*., 2010; Wang *et al*., 2010). The reduction in seed cotton yield was estimated to be 25.02 per cent due to mealy bug infestation in south Gujarat (Pawar *et al*., 2011). Various insecticides have been recommended for the management of mealybug (Dhawan *et al*., 2008; Nikam *et al*., 2010; Patel *et al*, 2010 and Rashid *et al*., 2011), but it is difficult to achieve proper control of mealy bug with insecticides due to waxy coating on the body of adult females (Rao and David, 1958; Dean *et al*., 1971). Besides, growing environmental and economic concerns involved in the use of pesticides, there is dire need to develop alternate measures for the management of sucking pests. Pesticides lead to many serious problems like pollution, health hazards, biodiversity threat, pest resurgence, pest resistance and secondary pest out-breaks in ecosystem (Bellows, 2001). Biological control is an effective means of achieving insect control (Pedigo and Rice, 2000). In natural ecosystem, the common green lacewing, *Chrysoperla carnea* (Stephens) has been recorded as an effective predator of aphids, including *Aphis gossypii* Glover (Burke and Martin,1956; Yuksel and Gocmen, 1992; Balasubramani and Swamiappan, 1994; Zaki *et al*., 1999) and has potential against cotton mealy bug (Sattar *et al*., 2007; Tanwar *et al*., 2007; Gautam *et al*., 2010; Ram and Saini, 2010; Rashid *et al*., 2012; Hameed *et al*., 2013), especially under pesticides free environment. The green lacewing, *Chrysoperla zastrowi sillemi* (Esben-Peterson) in the field preferred to oviposit on cotton followed by okra and it laid eggs on stalks on lower surface of leaves for oviposition followed by stem (Chakraborty *et al*., 2011) especially under pesticides free environment. The common green lacewing, *Chrysoperla zastrowi sillemi* seems to be a good candidate in IPM programme, as it is a voracious feeder (Balasubramani and Swamiappan, 1994), display a relative broad range of acceptable preys (Hydron and Whitecomb, 1979), easy to mass produced (Morrison, 1985 and El-Arnaouty, 1991) and is tolerant to some groups of pesticides (Hassan *et al*., 1989; Bigler and Waldburger, 1994 and Chen and Liu, 2002). The occurrence of *C. zastrowi sillemi* along with its prey insects in cotton ecosystem of south Gujarat necessities to evaluate the feeding potential of larvae of *C. zastrowi sillemi* as biological control agents to different stages of mealybug [eggs (ovisac), nymphs and female adults] with no choice and free choice feeding under laboratory condition.

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MATERIAL AND METHOD

The study of feeding potential of *C. zastrowi sillemi* on mealy bug was carried out in the Bio-control Laboratory, Department of Agricultural Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari during September to October 2014 at average room temperature of 24.03 ± 1.75 °C and relative humidity of 73.08 ± 2.86 per cent.

Maintenance of aphid and *Chrysoperla* culture

The initial cultures of mealy bug were collected from the cotton fields of Research farm, Main Cotton Research Station, Navsari Agricultural University, Surat during June to August 2014. For the purpose, mealy bug infested apical shoot were plucked and collected in perforated plastic bags, separately. The well matured adult female so obtained were released on 60 days old cotton plants raised in pots (45 CM height × 18.5 cm diamter) in the wire netting inventory of Bio-control Laboratory, Department of Agricultural Entomology, Navsari Agricultural University, Navsari for establishment. The culture so established within one and half month was utilized as prey for study the feeding potential of *C. zastrowi sillemi*. The laboratory culture of *C. zastrowi sillemi* was obtained from *Chrysoperla* Rearing Unit, Bio-control Laboratory, Department of Agricultural Entomology, N.A.U., Navsari. The pupae of *C. zastrowi sillemi* were placed in glass vial separately for adult emergence. Freshly emerged adults were released in rectangular oviposition cage of size 50 × 30 × 17 cm (Length x Width x Height) covered with a black muslin cloth inside the lid of the cage to facilitate egg laying. Semi solid paste of artificial diet (composed of 4 g of each ingredients of honey, proteinex powder, glucose, fructose, yeast powder, milk powder in equal quantity of distilled water with dispersible vitamin E capsule along with castor pollens) were placed on cotton swab in small plastic container at inside of the bottom of the oviposition cage for nutrition of adults. Eggs laid by the female on the under surface of lid of the cage on black muslin cloth which were removed individually with the help of a soft sponge pad for removing the stalk of eggs and kept individually with the help of fine camel hair brush and placed in separate plastic vials (5 x 2.5 cm) for further rearing and to avoid cannibalism. A special care was also taken to avoid mechanical injury to the eggs during detaching it from the stalk. On hatching, the larval instar of *Chrysoperla* was reared on laboratory host (eggs of rice grain moth, *Corcyra cephalonica* (Stainton) till pupae formation and again the eggs were collected as described above. Neonate larvae of *C. zastrowi sillemi* obtained through mass rearing as above were utilized for the study.

Assessment of feeding potential , consumption rate and developmental duration

The predatory potential of the larval instars of *C. zastrowi sillemi* against eggs (ovisac), nymphs and female adult (freshly formed) stage of mealy bug was studied in no choice and free choice feeding trials separately under laboratory conditions.

No choice feeding experiment: Twenty neonate larvae of *C. zastrowi sillemi* were kept individually in the plastic vial (5 × 2.5 cm). Three such sets of 20 larvae under plastic vials were prepared. One set was utilized for studying predatory potential against ovisac of mealy bug; second set for nymphs and third set for female adults were provided as prey insect stages throughout the total larval development. In all the three set, known number of prey insect was offered as food and the record was maintained on rate of consumption daily. On next day, again counted number of prey stage was offered as food and the consumption of prey insect was calculated. Predatory insect was observed daily in the morning and evening for change of instar. Number of prey consumed by the predatory larvae in each instar was calculated for each individual and the total consumption during total larval stage was worked out. The total larval duration of *C. zastrowi sillemi* was also estimated for ovisac, nymph and adult stage of mealy bug, separately and per day consumption of each stage of the prey was also calculated.

Free choice feeding experiment : Twenty neonate larvae of *C. zastrowi sillemi* were kept individually in the plastic vial (5 × 2.5 cm). The set of 20 larvae under plastic vials were prepared. The set was utilized for studying predatory potential against mixed stages of mealy bug (ovisac, nymph and adult) as prey. In the set, known number of mixed stages was offered as food and the record was maintained separately on rate of consumption daily. On next day, again counted number of mixed stages was offered as food and the consumption of prey insect was calculated. Predatory insect was observed daily in the morning and evening for change of instar. Number of prey consumed by the predatory larvae in each prey stage and in each instar was calculated for each individual and the total consumption during total larval stage was worked out. The total larval duration of *C. zastrowi sillemi* was also estimated and per day consumption of prey stages was also calculated.

RESULT

No choice feeding

Under no choice feeding experiment exclusively with eggs (ovisac) of mealy bug as food source, grubs of *C. zastrowi sillemi* consumed 163.65 ± 65.38, 511.70 ± 70.83 and 1211.25 ± 116.13 eggs (ovisac) of mealy bug in developmental durations of 2.55 ± 0.51, 3.05 ± 0.22 and 4.40 ± 0.50 days of first, second and third larval instars, respectively (Figure 1 and Table 1). The predator, *C. zastrowi sillemi* consumed 1778 to 2035 (Av. 1886.60 ± 74.88) eggs of mealy bug during developmental duration of 10 days. The prey consumption rate varied from 43.00 to 91.67 (Av. 61.69 ± 14.16), 137.67 to 191.00 (Av. 167.72 ±

19.43) and 256.50 to 314.00 (Av. 279.85 ± 17.44) eggs of mealy bug per day during first, second and third instars of *C. zastrowi sillemi*, respectively. During entire larval period prey consumption rate varied from 177.80 to 203.50 (Av. 188.66 ± 7.49) nymphs. When exclusively fed on nymphs of mealy bug, larva captured the nymph in between two sickle shaped mandibles and suck the inner body fluid by leaving behind the shrunken body skeleton. Grubs of *C. zastrowi sillemi* consumed 130.90 ± 23.51, 295.35 ± 40.35 and 419.25 ± 41.44 nymphs of mealy bug in developmental duration of 2.85 ± 0.37, 3.00 ± 0.46 and 4.15 ± 0.37 days of first, second and third larval instars, respectively. The grub of *C. zastrowi sillemi* consumed 812 to 899 (Av. 845.50 ± 23.44) nymphs of mealy bug during developmental durations of 9.5 to 10 (Av. 9.98 ± 0.11) days. The prey consumption rate varied from 36.00 to 51.33 (Av. 45.62 ± 3.72), 84.00 to 105.00 (Av. 98.75 ± 5.65) and 92.25 to 114.75 (Av. 101.06 ± 5.49) nymphs of mealy bug per day during first, second and third instars of *C. zastrowi sillemi*, respectively. During entire larval period prey consumption rate varied from 81.20 to 89.90 (Av. 84.76 ± 2.21) nymphs per day. Grubs of *C. zastrowi sillemi* consumed 25.70 ± 5.72, 57.05 ± 7.65 and 49.40 ± 5.05 female adults of mealy bug in developmental duration of 2.70 ± 0.47, 3.30 ± 0.47 and 2.90 ± 0.31 days of first, second and third larval instars, respectively. The grub of *C. zastrowi sillemi* consumed 119 to 141 (Av. 132.15 ± 6.37) female adults of mealy bug during developmental durations of 9.50 to 10.00 (Av. 9.98 ± 0.11) days. The prey consumption rate varied from 8.00 to 11.33 (Av. 9.47 ± 0.90), 15.33 to 19.00 (Av. 17.33 ± 1.04) and 14.00 to 19.67 (Av. 16.47 ± 1.68) female adults of mealy bug per day during first, second and third instars of *C. zastrowi sillemi*, respectively. During entire larval period prey consumption rate varied from 13.20 to 16.90 (Av. 14.87 ± 0.89) female adults.

Free choice feeding

Under free choice feeding with mixed stages of eggs, nymphs and female adults of mealy bug, the grubs of *C. zastrowi sillemi* consumed 96.55 ± 25.33, 313.65 ± 22.92 and 528.45 ± 19.23 mixed stages of mealy bug (eggs, nymphs and adult) in developmental durations of 2.90 ± 0.31, 3.1 ± 0.31 and 3.9 ± 0.31 days of first, second and third larval instars, respectively (Figure 1 and Table 2). The *C. zastrowi sillemi* consumed 886 to 998 (Av. 938.65 ± 35.09) numbers of mealy bugs (mixed stages) during developmental durations of 9 to 10 (Av. 9.75 ± 0.44) days. In free choice feeding, grub of *C. zastrowi sillemi* preferred eggs and nymphs of mealy bug more compared to female adult stage of mealy bug as indicated by consumption of 440.90 ± 18.93 eggs, 395.70 ± 15.82 nymphs and 102.05 ± 4.72 female adults out of 938.65 ± 35.09 number of mealy bug (mixed stages). The prey consumption rate varied from 23.50 to 43.00 (Av. 33.91 ± 5.49), 84.3 to 108.70 (Av. 98.70 ± 6.89) and 124.80 to 179.00 (Av. 136.57 ± 15.01) number of mealy bug (mixed stages) per day during first, second and third instars of *C. zastrowi sillemi*, respectively. During entire larval period prey consumption rate varied from 88.60 to 107.20 (Av. 94.93 ± 5.27) numbers of mealy bug (mixed stages) per day.

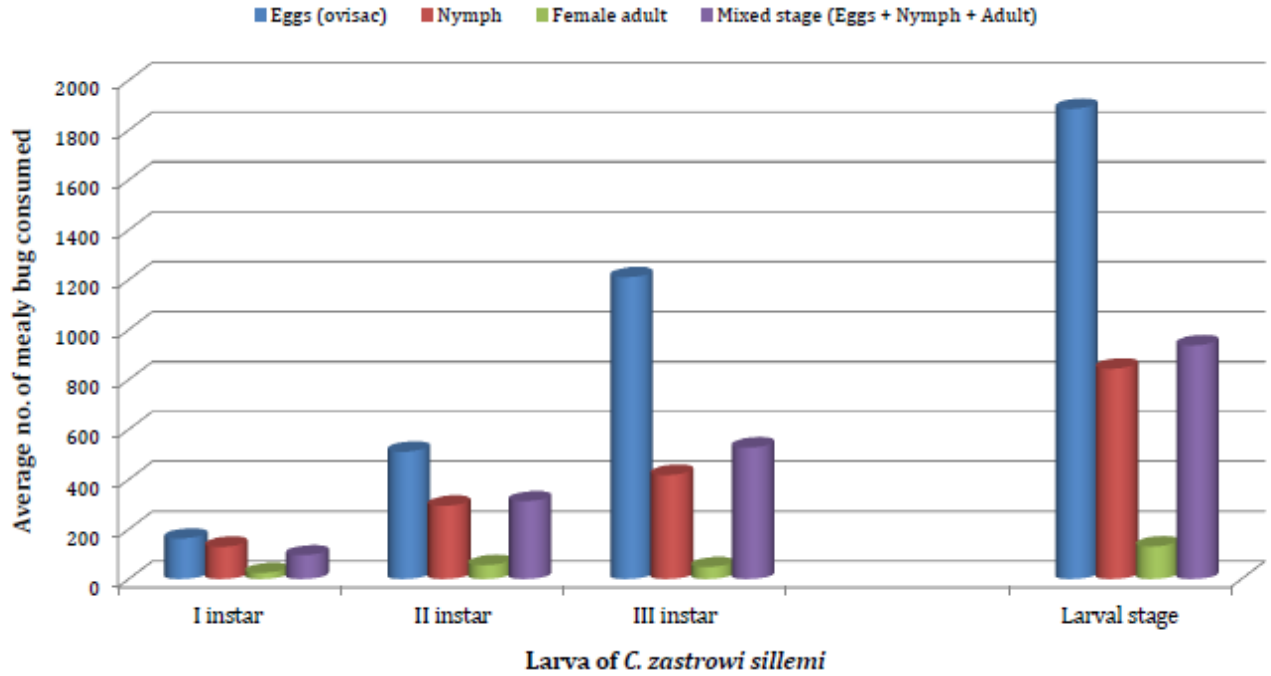

Fig 1. Feeding potential of *C. zastrowi sillemi* on eggs (ovisac), nymphs and adults (No choice feeding) and mixed stages (Free choice feeding) of mealy bug, *P. solenopsis*

Table 1. Feeding potential of *C. zastrowi sillemi* on different stages of *P. solenopsis* (no choice feeding)

Larval stages of *C. zastrowi sillemi*	No. of larvae exposed	No. of mealy bug consumed			Rate of consumption/day			Developmental duration (Days)		
		Min.	Max.	Av. ± S. D.	Min.	Max.	Av. ± S. D.	Min.	Max.	Av. ± S. D.
Eggs of Mealy bug as prey										
I instar	20	86	275	163.65 ±65.38	43.00	91.67	61.69 ±14.16	2	3	2.55 ±0.51
II instar	20	413	683	511.70 ±70.83	137.67	191.00	167.72 ±19.43	3	4	3.05 ±0.22
III instar	20	1044	1492	1211.25 ±116.13	256.50	314.00	279.85 ±17.44	4	5	4.40 ±0.50
Total	**60**	**1778**	**2035**	**1886.60 ±74.88**	**177.80**	**203.50**	**188.66 ±7.49**	**10**	**10**	**10.00 ±0**
Nymphs of Mealy bug as prey										
I instar	20	72	154	130.90 ±23.51	36.00	51.33	45.62 ±3.72	2	3	2.85 ±0.37
II instar	20	196	358	295.35 ±40.35	84.00	105.00	98.75 ±5.65	2	4	3.00 ±0.46
III instar	20	369	515	419.25 ±41.44	92.25	114.75	101.06 ±5.49	4	5	4.15 ±0.37
Total	**60**	**812**	**899**	**845.50 ±23.44**	**81.20**	**89.90**	**84.76 ±2.21**	**9.5**	**10.0**	**9.98 ±0.11**
Female adults of Mealy bug as prey										
I instar	20	17	33	25.70 ±5.72	8.00	11.00	9.47 ±0.90	2	3	2.70 ±0.47
II instar	20	46	75	57.05 ±7.65	15.33	19.00	17.33 ±1.04	3	4	3.30 ±0.47
III instar	20	42	59	49.40 ±5.05	14.00	19.67	16.47 ±1.68	2	3	2.90 ±0.31
Total	**60**	**119**	**141**	**132.15 ±6.37**	**13.20**	**16.90**	**14.87 ±0.89**	**9.50**	**10.00**	**9.98 ±0.11**

Table 2. Feeding potential of larva of *C. zastrowi sillemi on P. solenopsis* (free choice method)

Larval stages of *C. zastrowi sillemi*	Mathematical functions	No. of mixed stages of mealy bug consumed				Rate of consumption (No./day)				Duration in days
		Eggs	Nymphs	Adults	Total	Eggs	Nymphs	Adults	Total	
I instar	Min.	32	12	0	47	16.0	6.00	0.00	23.5	2
	Max.	82	37.00	12	129	27.33	12.33	4.00	43.0	3
	Av ± S. D.	63.65 ± 16.60	26.80 ± 7.98	6.05 ± 3.71	96.55 ± 25.33	22.43 ± 3.47	9.43 ± 2.04	2.02 ± 1.24	33.91± 5.49	2.9 ± 0.31
II instar	Min.	137	111	26	276	42.25	33.00	8.25	84.3	3
	Max.	181	150	43	369	51.33	46.00	12.67	108.7	4
	Av ± S. D.	151.25 ± 12.75	129.35 ± 9.35	33.05 ± 3.94	313.65± 22.92	47.52 ± 2.64	40.77 ± 3.69	10.41 ±1.32	98.7 ± 6.89	3.1 ± 0.31
III instar	Min.	206	225	59	499	51.50	56.25	14.75	124.8	3
	Max.	244	267	68	576	76.00	66.75	22.00	179.0	4
	Av ± S. D.	226.00 ± 10.62	239.50 ± 10.02	62.95 ± 2.98	528.45± 19.23	58.4 ± 6.53	59.88 ± 2.50	16.28 ± 1.98	136.57 ± 15.01	3.9 ± 0.31
Total	Min.	408	364	94	886	40.8	36.40	9.4	88.6	9
	Max.	477	422	113	998	50.2	46.10	11.4	107.2	10
	Av ± S. D.	440.90 ± 18.93	395.70 ± 15.82	102.05 ± 4.72	938.65± 35.09	44.59 ± 2.65	40.02 ± 2.35	10.32 ± 0.57	94.93 ± 5.27	9.75 ± 0.44

DISCUSSION

Under no choice feeding, the second and third instar grub of *C. zastrowi sillemi* fed more number of eggs than first instar and were voracious feeder. This might be due to more nutrition required for growth and development in subsequent instars. The first instar larvae of *C. zastrowi sillemi* had difficulty to open the full face of ovisac and feed on the eggs inside thread like cottony mass whereas bigger larvae fed easily by making rooms to fed eggs inside white cottony ovisac. The larvae of *C. zastrowi sillemi* developed little bit faster when fed on female adults of mealy bug than fed on nymphs and consumed less number of female adults than nymphs of aphids. This might be due to force feeding of nutritive diets in form of female adults of mealy bug. Under free choice feeding, the larvae of *C. zastrowi sillemi* preferred nymphs more comapared to eggs and female adults of mealybug owing to soft body, stationery behavour and small size of younger stages of mealy bug favoring the easy capture while there was diificulty of early instar larvae to open the full face of ovisac and feed the eggs and disliking of waxy coating on body of female adult stage of mealy bug. Further, there was not much variation in development duration of larvae of *C. zastrowi sillemi* when fed on mixed stages (eggs, nymphs and female adults) in free choice feeding then fed on nymphs and female adults of mealy bug in no choice feeding conditions. However, larvae of *C. zastrowi sillemi* developed little bit slower when fed exceptionally on eggs of mealy bug in no choice feeding conditions. Thus, in the present study, the larvae of *C. zastrowi sillemi* preferred eggs (ovisac) and nymphs of mealy bug as compared to freshly formed adult mealy bug as prey in free choice feeding condition. Different workers *viz.*, Sattar *et al*. (2007), Rashid *et al*. (2012) and Hameed *et al*. (2013) found that first instar nymphs of mealy bug was the most preferred food amongst three nymphal instars of mealy bug of *P. solenopsis*. In the present study, the first, second and third instar larvae of *C. zastrowi sillemi* consumed 72 to 154 (130.90 ± 23.51), 196 to 358 (295.35 ± 40.35) and 369 to 515 (419.25 ± 41.44) medium sized nymphs of *P. solenopsis*. In respective larval instars of *C. zastrowi sillemi*, Sattar *et al*. (2007) reported that the consumption of 125.8, 510.8 and 967.4 first instar nymphs of mealy bug while Rashid *et al*. (2012) found that the consumption of 406.0 ± 1.15, 426.3 ± 2.18 and 645.9 ± 2.45 and Hameed *et al*. (2013) reported that the consumption of 736.3, 3163.3 and 9131.7 first instar nymphs. These reports are more or less in support to the the present findings. Further, in present study, the larvae of *C. zastrowi sillemi* consumed 1178 to 2035 (1886.60 ± 74.88) eggs (ovisac), 812 to 899 (845.50 ± 23.44) nymphs (medium sized) and 119 to 141 (132.15 ± 6.37) female adult (freshly formed) during its development in no choice feeding condition. Earlier, Rabinder *et al*. (2008) reported that the larvae consumed 617.45 crawlers of *P. solenopsis* at the consumption rate of 30.79 crawlers per day in developmental period of 22.15 days and Aggarwal and Neetan (2014) reported that the single larva of *C. zastrowi sillemi* consumed 700.46, 245.00, 30.53 and 8.56 of first, second, third instar nymphs and female adults of cotton mealy bug, respectively during its entire life span.

Thus, the grub of *C. zastrowi sillemi* showed good potential against the younger stages of mealy bugs and can be taken advantage in Integrated Management of mealybug in cotton ecosystem.

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