Research Article

Pre-Imaginal Development of Different Prey Species on the Life History Parameters of Different Species of Green Lacewings (Neuroptera: Chrysopidae)

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Abstract | Green lacewings as predators have a wide prey range, but not all preys are equally suitable for a single lacewing. Studies were carried out to evaluate the suitability of three aphid species on the pre-imaginal development of three species of green lacewings. Developmental stages of three different species of green lacewings, *Chrysoperla nipponensis*, *Plesiochrysa ramburi* and *Apertochrysa* sp. were provided with three different prey species, *Aphis craccivora*, *Rhopalosiphum maidis* and *Corcyra cephalonica* under the laboratory conditions (25±2 °C). The results indicated that a significantly increased pre-imaginal (19.93±0.24) and mean average days (70.33±0.55) of *C. nipponensis* on *R. Maidis* and also a significantly increased pre-imaginal (20.84±0.49), (21.22±0.97) and mean average days (74.18±0.33), (68.72±0.30) of *P. ramburi* and *Apertochrysa* sp. on the host of *R. maidis*. Whereas a significantly decreased pre-imaginal and total mean average days were observed on *C. cephalonica* in all species of green lacewings. A maximum fecundity of *Apertochryca* sp. (645.70±8.53), *C. nipponensis* (618.70±12.23) and *P. ramburi* (590.66±5.29) were found on the host of *C. cephalonica* while lowest fecundity of *P. ramburi* (508.17± 6.91), *Apertochryca* sp. (517.10± 8.13) and *C. nipponensis* (581.10± 10.91) were observed on *R. maidis*.

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Introduction

Human interests are always threatened by the presence of pest and pesticides as the most extensively applied methods for pest control. Approximately 2.7 million tons of pesticides were applied in the world in 2011 to control noxious pests (FAOSTAT, 2013) however, pesticide usage has many adverse effects on human and their environment, often results in pest resurgence and the killing of non-target and beneficial individuals (Weathersbee and Mckenzie, 2005). Moreover, either directly or indirectly, pesticides are responsible for over 25 million cases of pesticides poisoning and 20,000

unintended death (Hajek, 2004; Ulhaq et al., 2006) considering these adverse impacts, scientists always strive for alternate methods to control pests that could provide better pest management with less hazardous to humans and their environment.

Biological control is a method to control pests through the use of natural enemies as it is environmentally sound and economically efficient in mitigating the pest densities (Sarwar et al., 2012, 2013a, 2013b, 2014). The natural enemies are used in classical, augmentative and inundative biological control programs (Tuusalo, 1984). During recent years, the use of biological control agents such as green lacewings has shown potential to manage pest population below their economic threshold. Accordingly, many integrated management programs with biological control as their key component have been employed against many damaging pests in various crops throughout the world (Canard et al., 1984).

Chrysopids feed on various aphid species, including *Aphis glycines* Matsumura (Ragsdale et al., 2011), *Myzus persicae* Sulzer (Pappas et al., 2007), *Diuraphis noxia* Mordvilko (Messina and Sorenson, 2001), *Aphis gossypii* Glover (Liu and Chen, 2001), *Lipaphis erysimi* Kalt. (Kumar and Singh, 2001), *Rhopalosiphum maidis* Fitch (El-Serafi et al., 2000), *Aphis craccivora* Koch (Saminathan et al., 1999) and *Monellia caryella* Fitch (Liao et al., 1985). They also feed on the eggs of Lepidoptera such as *Corcyra cephalonica* Stainin (Bansod and Sarode, 2000), *Anagasta kuehniella* Zeller (Zheng et al., 1993) and *Sitotroga cerealella* Olivier (López-Arroyo et al., 1999).

The green lacewing, *Chrysoperla sinica* (Tjeder) (Neuroptera: Chrysopidae), is distributed throughout China (Xu et al., 1999) and a key predator of many important agricultural pests (notably aphids, leafhoppers, thrips, mites and Lepidoptera) (Penney et al., 2000; Principi and Canard, 1984; Ding and Chen, 1986; Zheng et al., 1993; Atlihan et al., 2004; Wang and He, 2006; Ragsdale et al., 2011). However, the adults are not predators and feed mostly on plant nectar, honeydew and pollen (Villenave et al., 2006; Li et al., 2008). The larvae forage actively and are voracious predators of various species of prey (Xu et al., 1999; Duelli, 2001) and frequently used in augmentative and inundative biological control of agricultural pests (Zhou et al., 1991; Senior and McEwen, 2001). In order to optimize the conditions used by bio-control companies to rear predator and achieve a more cost-effective method of rearing various other species of prey and artificial diets have been used (Lee and Lee, 2005; Uddin et al., 2005; Kazemi and Mehrnejad, 2011). Therefore, it is important for the successful development of pest management programs that utilize predator as a bio-control agent to identify alternative high quality prey/food. However, there are no studies on the effect of different prey species on the pre-imaginal development and reproduction of adults of *Chrysoperla nipponensis*, *Plesiochrysa ramburi* and *Apertochrysa* sp. The importance of nutritional quality of the prey for these predators is also unknown. The aim of present study was to evaluate pre-imaginal development of different prey species on the life history parameters of different species of green lacewings in terms of survival, development and reproduction under laboratory conditions.

Materials and Methods

Culture of factitious host, Corcyra cephalonica

Initially the culture of rice moth, *C. cephalonica* was obtained from the Department of Plant Protection, University Putra Malaysia. To establish the culture of factitious host, the ingredients such as maize, rice, wheat and semolina (1:1:1:1) were autoclaved to prevent any unwanted infestation and/ or pathogens. Approximately after one hour of cooling the sterilized ingredients, they were mixed and placed in plastic cages measuring 37 × 28cm × 22cm. Eggs of *C. cephalonica* were spread over the diet inside the cage. Rearing conditions for culture were 25 ± 2 °C, 55-85% RH and 12L: 12D photoperiod to develop *C. cephalonica* to adult stage that was collected for matting in a plastic cage. The eggs produced were collected in a glass plate and placed in the freezer to exhaust egg viability.

Culture of natural preys, Aphis craccivora and Rhopalosiphum maidis

The culture of natural preys, *Rhophalosiphum maidis* and *Aphis craccivora* was established on their respective hosts in the laboratory conditions. Initially, the culture was collected from the farmer field of Ladang II, near the insectary of University of Putra Malaysia. The aphids were maintained in cages measuring 20 × 13cm × 10cm size. The top of the cages was covered with organza cloth for aeration and the rearing conditions for culture were 25 ± 2°C. The rearing of preys was carried out for one month to obtain a sufficient

number of prey for the larvae of predators. Fresh host nymphs/ adults were provided to the all larval instars of green lacewing species in the petri dishes.

Culture of green lacewings, Chrysoperla nipponensis, Plesiochrysa ramburi and Apertochrysa sp.

The experimental adults of green lacewings were obtained from the colony. Adults were maintained in cylindrical glass jars (18 cm in diameter and 25 cm high). The standard adult diet was composed according to Alasady et al. (2010). It comprised of 2.5 g yeast, 3 g sugar, 2.5 ml honey, 3 g milk powder (instead of casein) 2.5 ml distilled water and the mixture forms a slurry that was provided on a plastic strip in the rearing cages with measurement of 2 × 15cm. Thus, each larva of all respective species of green lacewings was reared separately in trays of ELISA wells. Rearing conditions for stock cultures of chrysopids were 25 ± 2°C.

In present study, three different species of green lacewings, *Chrysoperla nipponensis*, *Plesiochrysa ramburi* and *Apertochrysa* sp. were used with three different host species, *Aphis craccivora*, *Rhopalosiphum maidis* and *Corcyra cephalonica* to investigate the suitability of food for the immature stages. Third- and fourth instar nymphs of each aphid species were supplied daily to each species of green lacewing larvae (ad libitum 15–200 aphids according to larval age) throughout their larval development. In the case of *C. cephalonica* eggs, fresh eggs were supplied daily to larvae (ad libitum 50–250 eggs according to larval age). The pre-imaginal development and reproductive parameters were observed under the laboratory conditions 25±2 °C. After hatching of eggs of each green lacewing species, thirty (30) young larvae were randomly selected and provided each prey species separately in trays of ELISA wells. After reaching to the pupal stage, twenty-five (25) pupae were randomly selected from each treatment to find the pupal days and then from each treatment ten (10) pairs of adults sorted according to sex were confined to check the fecundity and longevity of both males and females. Similarly, these adults were supplied with the artificial diet described above for colony maintenance.

Statistical analysis

The software SPSS (SPSS Inc., Chicago, IL, US) was used for data analysis. The one-way analysis of variance (ANOVA) was used for analysis of data and means were compared using Tukey test at $P<0.05$.

Results and Discussion

A significant difference was observed in the developmental stages of green lacewing, *Chrysoperla nipponensis* against prey species, *Rhopalosiphum maidis*, whereas short developmental days of *C. nipponensis* were observed on the host of *C. cephalonica*. However, statistically no difference was observed on 1st larval instar in comparison to other treatments. The highest and significant increased fecundity was observed on the *C. cephalonica* and the lowest fecundity was recorded on *R. maidis* Table 1. A significant difference was recorded in all developmental periods of green lacewing *Plesiochrysa ramburi* when provided prey species, *A. craccivora*, while the short developmental periods of *P. ramburi* were observed on *C. cephalonica*. Statistically no significant difference was observed between the hosts of *A. craccivora* and *R. maidis* respectively. The highest number of fecundity was seen on the host of *C. cephalonica* and low fecundity was observed when supplied the host *R. maidis* as mentioned in Table 2. The developmental periods of green lacewing, *Apertochrysa* sp. were significantly increased when the green lacewing, *Apertochrysa* sp. was provided *A. craccivora*, although a significant decrease in life stages of *Apertochrysa* sp. were observed against *C. cephalonica*. While no significant difference was observed between 1st and 2nd instars of *Apertochrysa* sp. in all other treatments. Statistically maximum fecundity was observed when the host, *C. cephalonica* were provided, whereas the minimum fecundity was noticed on the host of *A. craccivora* as indicated in the Table 3. The green lacewing larvae feed on a variety of soft-bodied insects (Tauber and Tauber, 1983; Ding and Chen, 1986; Zheng et al., 1993; Rao et al., 2003; Rajabaskar, 2007) and are considered to be key predators of many agriculturally important pests (Principi and Canard, 1984; Ragsdale et al., 2011). It is widely reported that unsuitable food can extend the pre-imaginal development of chrysopids and decrease the survival, fecundity and longevity of the adults (Principi and Canard, 1984; Obrycki et al., 1989; Zheng et al., 1993). In this study we evaluated the pre-imaginal developmental period as well as adult longevity and fecundity of green lacewings, *Chrysoperla nipponensis*, *Plesiochrysa ramburi* and *Apertochrysa* sp. provided with different species of prey. Generally, the larvae of all species of green lacewings that were reared on factitious and natural preys had shorter pre-imaginal developmental periods and the adults lived longer and were more fecund except those

Table 1: *Effect of prey species on the developmental stages on green lacewing, Chrysoperla nipponensis.*

Developmental stages	Different hosts of C. nipponensis		
	A. craccivora	R. maidis	C. cephalonica
1st instar	3.50±0.93a	3.56±0.62a	3.26±0.63a
2nd instar	3.53±0.62a	4.33±0.71b	3.43±0.68a
3rd Instar	3.50±0.50a	4.10±0.54b	3.26±0.44a
Pupal stage (days)	6.92±0.08b	8.00±0.15a	6.36±0.15c
Pre-imaginal days	17.41±0.33b	19.93±0.24a	16.41±0.20c
Male days (longevity)	46.40±1.49a	47.50±1.37a	39.50±0.83b
Female days (longevity)	54.30±1.44a	55.80±0.61a	47.20±0.80b
Total mean average (days)	68.51±0.60a	70.33±0.55a	59.76±0.37b
Fecundity	608.80±4.10ab	581.10± 10.91b	618.70±12.23a

Mean (± SE) followed by different letters within a column are significantly different by Tukey Test (P<0.05).

Table 2: *Effect of prey species on the developmental stages on green lacewing, Plesiochrysa ramburi.*

Developmental stages	Different hosts of P. ramburi		
	A. craccivora	R. maidis	C. cephalonica
1st Instar	3.90±0.81a	3.76±0.59ab	3.12±0.29b
2nd Instar	4.02±0.88a	3.96.±0.41a	3.51±0.45b
3rd Instar	3.90±0.75a	3.70±0.30a	3.02±0.20b
Pupal stage (days)	9.02±0.14a	8.85±0.27a	7.32±0.44b
Pre-imaginal days	20.84±0.49a	20.07±0.21a	17.01±0.39b
Male days (longevity)	47.20±0.19a	45.80±0.36a	40.27±0.73b
Female days (longevity)	59.49±1.26a	56.89±1.11ab	53.66±1.14b
Total mean average (days)	74.18±0.33a	71.41±0.88a	63.97±0.80b
Fecundity	533.40±3.18b	508.17± 6.91b	590.66±5.29a

Mean (± SE) followed by different letters within a colum are significantly different by Tukey Test (P<0.05).

Table 3: *Effect of prey species on developmental stages on green lacewing, Apertochrysa sp.*

Developmental stages	Different hosts of Apertochrysa sp.		
	A. craccivora	R. maidis	C. cephalonica
1st Instar	4.10±0.11a	3.90±0.37a	3.96±0.23a
2nd Instar	3.90±0.19a	3.80±0.31ab	3.66±0.28a
3rd Instar	4.30±0.15a	4.10±0.39a	3.26±0.14b
Pupal stage (days)	8.92±0.81a	8.60±0.49a	7.48±0.39b
Pre-imaginal (days)	21.22±0.97a	20.40±0.38a	18.09±0.26b
Male days (longevity)	43.10±0.69a	42.89±0.17a	40.15±0.66b
Female days (longevity)	51.60±1.38a	52.18±1.19a	49.00±1.29b
Total mean average (days)	68.72±0.30a	67.93±0.42a	62.66±0.44b
Fecundity	554.25±9.19c	517.10± 8.13b	645.70±8.53a

Mean (± SE) followed by different letters within a column are significantly different by Tukey Test (P<0.05).

reared-on *C. cephalonica*. This indicates that the species of prey is of paramount importance as part of a balanced source of food (Evans et al., 1999) to ensure the nutrients that enhance the pre-imaginal developmental period and the longevity and fecundity of the later stages of green lacewings. However, rearing of different species of green lacewings on range of different species of prey resulted in little variation, which might indicate that these predators are well adapted to these particular natural prey niches. The shorter pre-imaginal period of larvae of *P. ramburi* and *Apertochrysa* sp. was observed when supplied with

nymphs of *R. maidis* as compared to *A. craccivora* that accords with the results of Obrycki et al. (1989), who reported that larvae of *Chrysopa oculata* Say take less time to develop when reared on *R. maidis*. Above all, rearing of green lacewings, *Chrysoperla nipponensis*, *Plesiochrysa ramburi* and *Apertochrysa* sp. on *C. cephalonica* eggs resulted in higher fecundity as compared to those reared on aphids, as previously recorded by Wang and Nordlund (1994); Pappas et al. (2007); Huang and Enkegaard (2009), suggesting that eggs are very nutritious. This probably indicates variations among predators in their physiological responses to the different nutrient contents of prey and such difference might be due to differences among the species in their nutritional requirements (El-Arnaouty et al., 1994). Finally, our study indicates that of all the prey tested the eggs of rice moth, *C. cephalonica*, are the most suitable food for the mass rearing of all three species of green lacewings, *Chrysoperla nipponensis*, *Plesiochrysa ramburi* and *Apertochrysa* sp. However, further studies are required to evaluate the field performance of these predators in Malaysia in terms of feeding on aphids when they are mass reared on the eggs of Lepidoptera.

Conclusions and Recommendations

In present investigation we observed that significantly increased developmental stages of green lacewing species *Plesiochrysa ramburi* and *Apertochrysa* sp. on the host of *A. craccivora*, and longer duration of *Chrysoperla nipponensis* were seen on the host of *R. maidis*. However, shorter developmental stages of all green lacewing species were found on the host of *C. cephalonica*. Similarly, the highest fecundity of all green lacewing species was observed on the host of *C. cephalonica* and minimum fecundity were seen on the host of *R. maidis*. This might be due to the high level of protein in eggs of *C. cephalonica* that green lacewing is able to complete their life cycle in earlier days and also support them for increasing fecundity in short duration. Moreover, this information would be helpful for optimizing the mass rearing of predators and for understanding its population dynamics in the field in the presence/absence of the various species of prey tested.

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Author's Contributions

S.A. Memon conceived the idea of data collection and overall management of the manuscript, A. Ali and I.A. Rajput analyzed the data, M.N. Narejo, worked on plagiarism, K. Ghulam, Reviewed the manuscript. M. Adeel and K.A. Memon contributed to format the manuscript according to the standard of journal. O. Dzolkhifli provided technical inputs at every step of this work.

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