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Biology and predatory potential of chrysopids on invasive coconut rugose spiralling whitefly *Aleurodicus rugioperculatus* Martin

K Elango[1]*, S Jeyarajan Nelson[1], S Sridharan[1], V Paranidharan[2] & S Balakrishnan[3]

[1]Department of Agricultural Entomology; [2]Department of Plant Pathology; [3]Department of Spices and Plantation Crops, Tamil Nadu Agricultural University, Coimbatore - 641 003, Tamil Nadu, India

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The relatively new invasive rugose spiralling whitefly (RSW) *Aleurodicus rugioperculatus* (Hemiptera: Aleyrodidae) has become a serious threat to oil palm, particularly coconut plantation, in southern India. Here, we report biology and foraging potential of predatory neuropteran Green lace wings *Chrysoperla zastrowi sillemi* (Esben-Petersen) and *Mallada boninensis* (Okamoto) (Chrysopidae) on against RSW. Results revealed that *A. rugioperculatus* served as a suitable host for the both chrysopid predators. *C. z. sillemi* completed its life cycle in 19.91±1.90 days with a larval (grub) period of 9.44±3.91 days and adult longevity was 24.10±1.87 days. The developmental period of *M. boninensis* was 22.3±2.93 days, with a larval period of 11.85±1.71 days, while the adult longevity was 19.25±1.52 day. In the laboratory experiment, all the larval stages of the predators were observed to feed on *A. rugioperculatus*. It was observed that the 3rd instar grub of *C. zastrowi sillemi* with the developmental period of 3.24±1.73 days consumed a maximum of 313.2 whiteflies (all the life stages) followed by second and 1st instar grub stages of the predator, which consumed mean number of 200.2 and 140.2 eggs and nymphs of *A. rugioperculatus*, respectively during their developmental period of 3.58±1.84 and 2.62±1.34 days, respectively. In the case of *M. boninensis*, a single grub could consume a total of 929.8 whiteflies (both eggs and nymphal stages) during its total larval period of 9.44±3.91 days.

Keywords: Biocontrol, Green lacewings, Foraging, IPM, Rugose spiralling whitefly, *Chrysoperla zastrowi sillemi*, *Mallada bonienesis*

India has witnessed invasion of 118 exotic species of insects which includes several economically important whiteflies. Presently, 442 species of whiteflies belonging to 32 genera are known from India[1]. A new addition to the list of whitefly species found in Florida is *Aleurodicus rugioperculatus* Martin, (Hemiptera: Sternorrhyncha: Aleyrodidae), originally called the gumbo limbo whitefly and rugose spiralling whitefly (RSW). It is an introduced pest, endemic to Central America, and was reported for the first time in Florida from Miami-Dade County in 2009[2]. It is naturally distributed in Belize, Guatemala, Mexico and subsequently, it has spread to 22 other countries in Central and South America, including Florida, USA and India is the only country in the Oriental region where the whitefly has been introduced[3]. In India, *Aleurodicus rugioperculatus* is reported from Tamil Nadu, Karnataka, Kerala Andhra Pradesh, Goa, Assam, West Bengal, Maharashtra and Gujarat[4-6]. The first report on incidence of RSW in coconut palms occurred in 2016 at Pollachi, Coimbatore district, western agro climatic zone of Tamil Nadu[7]. It is a highly polyphagous pest and attacks a wide range of host plants including palms, woody ornamentals and fruit crops. Coconut, oil palm and banana are among the most preferred host plants. Whitefly feeding causes stress to the host plant by removing water and nutrients and also by producing honeydew, which covers the upper surface of the lower leaves and results in the growth of sooty mold, which can potentially reduce photosynthesis of the plant[8]. Severe damage by RSW has been reported from Tamil Nadu, Karnataka, Kerala Andhra Pradesh and the infestation ranged from 35-40% in coconut and 24-38% in banana. This new invasive pest has been observed on banana leaves and fruits also in Tamil Nadu[9].

Abiotic factors play a key role in determining the incidence and dominance of a particular pest and their natural enemies in a crop ecosystem. Deficit in annual rainfall, increased temperature and reduced humidity are considered the prime reasons for the flare-up and spread of RSW[10]. At present, farmers solely rely on synthetic chemical insecticides for management of RSW in coconut. Further, frequent applications of insecticides leads to development of tolerance, resistance, resurgence, and also residual toxicity, and thereby adversely affect the humans and the environment as well. However, natural enemies play a major role in bringing down the whitefly population in nature.

Green lacewings (Neuropter: Chrysopidae) are among the most common natural enemies of pest

*Correspondence:
E-Mail: elaento@gmail.com

insects in agricultural and Horticultural ecosystems worldwide[11]. Among the chrysopids *Chrysoperla zastrowi sillemi* (Esben-Petersen) and *Mallada boninensis* (Okamoto) are the most intensely studied species because of their wide geographical distribution, good searching ability and easy rearing in the laboratory. They are regarded as major cosmopolitan predators of some whiteflies and aphids[12]. The larvae of chrysopids feed on a wide range of pest species such as mealybugs, aphids, thrips, whiteflies mites and eggs of insect pests while adults are free-living and feed only on nectar, pollen and honeydew[13]. It is now commonly reared in laboratory and used extensively all over the country and has significant potential for commercialization and use against a variety of crop pests in combination with other insect pest management tactics[12]. We have also earlier shown that the Green lacewings *C. z. sillemi* and *M. boninensis* to be efficient predators of *A. rugioperculatus* in Tamil Nadu[14,15].

Here, we studied the biology and foraging potential of these two green lacewings, *C. zastrowi sillemi* and *M. boninensis* on the invasive pest, rugose spiralling whitefly (RSW) *Aluerodicus rugioperculatus*.

Materials and Methods

Source of test insects

Freshly laid eggs of *C. z. sillemi* and *M. boninensis* were collected from coconut field and mass cultured using of *Corcyra cephalonica* Stainton eggs in laboratory[16]. The cultures were maintained in the biological control laboratory (30±2°C and 75±5% RH), Tamil Nadu Agricultural University, Coimbatore.

Biology of *C. zastrowi sillemi* and *M. boninensis on RSW*

Thirty eggs of *C. zastrowi sillemi* were kept in a small container and as soon as hatched, the larvae were provided with the fifty mixed population of different instars of *A. rugioperculatus* nymphs for the feed up to pupation of predator. Life cycle parameters egg incubation period, larval and pupal period (days) were recorded daily. After the adult emergence, 5 pairs of adults were collected and maintained in the adult rearing cage. Biological parameters such as adult survival, the longevity of male and female, pre and post-oviposition period (days) and fecundity per female were recorded daily. The experiment was conducted in a Completely Randomized Design (CRD) with five replications. The same method was followed for determining the biology of *M. boninensis.*

Foraging potential of *C. zastrowi sillemi* and *M.boninensis* against *RSW*

The predators were placed individually in small plastic containers (20×10 cm) covered with Khada cloth. Study was conducted with fifteen individuals for each predator, using the egg and nymphal instars of *A. rugioperculatus* separately. Each instar of grub stage was considered as one treatment and there were three treatments replicated five times to assess the predatory potential. Based on the length, width and the size of the grub, the instar of the grub was fixed[17]. The predators were examined daily and fresh coconut leaves with *A. rugioperculatus* population were provided on alternate days. The leaves used in the experiment were examined with the assist of a Leica image analyser (M205C), the initial number of eggs and each instar of the RSW before exposure to the predator were counted, as well as the number of *A. rugioperculatus* population fed by the predator on each day of the life period. The study was continued till the mortality of the predator and the longevity was worked out. The fecundity, incubation period, first, second, 3rd instar grub period, pre-pupal, pupal and total developmental period along with adult longevity were studied for both the predators.

Statistical analysis

The data were subjected to statistical analysis adopting completely randomized block design with 3 treatments and 5 replications and the mean values of treatments were separated by Least Significant Difference (LSD)[18] using AGRES ver. (7.01), Pascal International Solutions.

Results and Discussion

Biology of chrysopids

Egg incubation period was 3.14±1.32 days in *C. z. sillemi* and 3.10±0.55 days in *M. boninensis*, when reared on *A. rugioperculatus*. Total grub period of *C. zastrowi sillemi* was 9.44±3.91 days which includes developmental periods of first (2.62±1.34), Second (3.58±1.84) and 3rd instar (3.24±1.73 days) instar grubs, respectively (Table 1). Compared to *C. z. sillemi*, *M. boninensis* has high duration period around 11.85±1.71 days. All the instars of the grub stages effectively fed on *A. rugio-perculatus* and entered into the pupal stage. Pupal period of both predators was 7-8 days. Adult longevity was 19.25±1.52 days in *M. boninensis*, while it was 18.28±1.67 days in *C. z. sillemi* (Table 1). Total developmental period of *M. boninensis* was 24.2 days,

whereas in the case of *C. zastrowi sillemi* it was 22.8 days[14]. The longevity of female and the total developmental period of *M. desjardinsi* was reported as 27.66±1.69 days and 24.16±0.99 days, respectively, when fed on *A. dispersus*[19].

Predatory potential of *C. zastrowi sillemi* and *M.boninensis* on *A. rugioperculatus*

The 3rd instar grub of *C. z. sillemi* with the developmental period of 3.24±1.73 days consumed a maximum of 313.2 whiteflies (Nymphs & eggs) followed by second (200.2 eggs & nymphs) and 1st instar grubs (140.2 eggs and nymphs) of *A. rugio-perculatus* during their development period of 3.58±1.84 and 2.62±1.34 days, respectively (Table 2 and Fig. 1A). Further, single *C. zastrowi sillemi* grub could consume a total of 653.6 eggs and nymphs during its entire larval period of 9.43 days. Grub preferred to feed on both eggs and nymphs of RSW. The results indicate the potential of *C. zastrowi sillemi* as an effective predator for *A. rugioperculatus*. These findings are consistent with what have been reported by others against spiralling whitefly[19,20]. Single release of *C. zastrowi sillemi* at 4 grubs per plant was effective against *B. tabaci* in tomato[21]. The predatory potential of *Mallada boninensis* on the eggs and different nymphal instars of *A. rugioperculatus* revealed that maximum number of *A. rugioperculatus* (eggs and nymphs) (377.80) was consumed by 3rd instar grub during its developmental period of 5.10±0.72 days followed by 2nd instar grub of *Mallada boninensis* which consumed 298.2 in 4.35±0.49 days (Table 2 and Fig. 1). First instar predatory grub (with a developmental period of 2.40±0.50 days) consumed 253.8 eggs and nymphs. A total of 929.8 *A. rugio-perculatus* (eggs and nymphs) were consumed by *Mallada boninensis* during its total larval period of 9.44±3.91 days. The *M. desjardinsi* first stadium has been shown to have the least capacity to consume various life stages of RSW. Our findings are largely in agreement with the observations reported above on the spiralling whitefly[22]. The prey consumption of lacewings increases with advancement in larval instars. Second and third stadia of *M. desjardinsi* consumed a much larger number of *A. disperses* individuals[23]. This clearly demonstrates that the 3rd instar lacewings are far more voracious than the second and first instars[24,25].

Table 1 — Biology of Chrysoperla zastrowi sillemi and Mallada bo

Life stages of Predator	*C. z. sillemi* Duration (days±SD*)	Range (days)	*M. boninensis* Duration (days±SD*)	Duration (days±SD*)
Egg	3.14±1.32	2-4	3.10±0.55	2-4
1st instar	2.62±1.34	2-5	2.40±0.50	2-3
2nd instar	3.58±1.84	3-5	4.35±0.49	4-5
3rd instar	3.24±1.73	3-4	5.10±0.72	4-6
Total grub period	9.44 ±3.91	9-13	11.85±1.71	10-14
Pre pupal period	2.52±0.51	1-3	1.65±0.50	1-2
Pupal peiod	7.33±3.42	7-9	7.35±0.67	6-8
Total develop-ment period	19.91±1.90	13-18	22.30±2.93	18-26
Male longevity	18.28±1.67	14-20	11.95±1.23	10-14
Female longevity	24.10±1.87	19-27	19.25±1.52	17-22

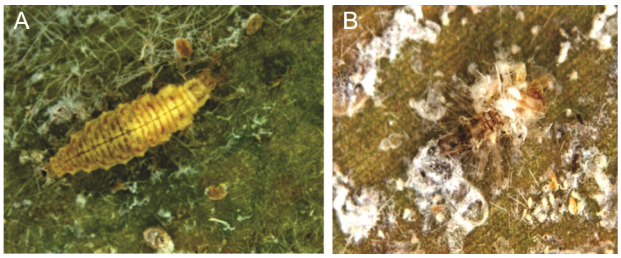

Fig. 1 — Foraging potential of chrysopids on Rugose spiralling whitefly. (A) *Chrysoperla zastrowi sillemi*; and (B) *Mallada boninensis* [The third instar grubs of *Chrysoperla zastrowi sillemi and Mallada boninensis* were effectively preying on eggs and nymphs of RSW with the help of pincer-like mandibles]

Table 2 — Feeding potential of *Chrysoperla zastrowi sillemi* and *Mallada boninensis* on Rugose spiralling whitefly

Stages of the predator	Number of *A. rugioperculatus* consumed by chrysopid predators per stage* *Chrysoperla zastrowi sillemi* Eggs	1st instar	2nd instar	3rd instar	IV instar	Total	*Mallada boninensis* Eggs	1st instar	2nd instar	3rd instar	4th instar	Total
1st instar	28.2 (5.31)^{c}	34.4 (5.86)^{c}	29.2 (5.40)^{c}	26.2 (5.12)^{c}	22.2 (4.71)^{c}	140.2 (17.69)^{c}	40.4 (6.35)^{c}	56.4 (7.50)^{c}	61.2 (7.82)^{c}	58.8 (7.66)^{c}	37 (6.08)^{c}	253.8 (19.45)^{c}
2nd instar	43.8 (6.61)^{b}	49.6 (7.04)^{b}	39.8 (6.30)^{b}	34.4 (5.86)^{b}	32.6 (5.70)^{b}	200.2 (14.49)^{b}	51.2 (7.15)^{b}	66.8 (8.17)^{b}	68.8 (8.29)^{b}	62 (7.87)^{b}	49.4 (7.02)^{b}	298.2 (17.28)^{b}
3rd instar	60.2 (7.75)^{a}	64.2 (8.01)^{a}	70.2 (8.37)^{a}	61.8 (7.86)^{a}	56.8 (7.53)^{a}	313.2 (11.83)^{a}	70.2 (8.37)^{a}	80.8 (8.98)^{a}	84.4 (9.18)^{a}	81.0 (9.00)^{a}	61.4 (7.83)^{a}	377.8 (15.94)^{a}
Total	132.2	148.2	139.2	122.4	111.6	653.6	161.8	204	214.4	201.8	147.8	929.8
SEd	0.1860	0.2067	0.2220	0.1953	0.1554	0.1021	0.1776	0.2132	0.2115	0.1854	0.1585	0.1420
CD (P = 0.05)	0.4052	0.4503	0.4837	0.4256	0.3386	0.2140	0.3869	0.4644	0.4608	0.4039	0.3453	0.2841

*Mean of five replications; significant at 1%; figures in parentheses are square root transformed values; in a column, means followed by a common letter(s) are not significantly different by DMRT (P = 0.05); (Df =14)

Conclusion

The above study has demonstrated that chrysopid predators, *Chrysoperla zastrowi sillemi* and *Mallada boninensis* feed and complete their life cycle on *Aleurodicus rugioperculatus*. A single grub of *M. boninensis* was found to consume a mean number of 929.8 whitefies stages, both eggs and nymphal instars, during its total larval period of 9.44±3.91 days than *C. z. sillemi* (653.6 whiteflies with 9.43 days of larval period). The findings suggest that these indigenous neuropteran predators could play a major role in controlling the population of invasive Rugose Spiralling Whitefly (RSW).

Conflict of interest

Authors declare no competing interests.

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