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Functional response and density dependent feeding interaction of *Pseudomallada astur* Banks (Neuroptera: Chrysopidae) against Rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae)

N.B.V. CHALAPATHI RAO, B. S. RAMANI and B.V.K. BHAGAVAN

Horticultural Research Station, DrY.S.R.Horticultural University, Ambajipeta -533214 East Godavari, Andhra Pradesh, India

E-mail: chalapathirao73@gmail.com

ABSTRACT : A study on feeding potential and functional response of the chrysopid predator, *Pseudomallda astur* Banks to rugose spiraling whitefly (RSW), *Aleurodicus rugioperculatus* Martin was carried out at Horticultural Research Station, Ambajipeta , Dr YSR Horticultural University, Andhra Pradesh. The study revealed that mean number of RSW eggs consumed increased with advancement of larval instars of *P. astur*. The maximum number of RSW eggs were consumed by 1st instar at prey density of 80 eggs (94.75 %) and minimum at highest density of 200 eggs (72.25%). The 2nd instar of *P. astur* also consumed more RSW eggs at a prey density of 100 eggs (96.5 %) and minimum at highest density of 250 eggs (75.52%). The third instar was more voracious and highest consumption was recorded at a prey density of 120 eggs (97.25%) and lowest at 300 eggs (70.27 %). All the larval instars stages followed a Type III functional response. An initial observation on feeding potential of the predator under field conditions was also found to be highly promising. Thus, this predator could be successfully utilised in biological control programs of rugose spiralling whitefly.

Keywords: Rugose spiraling whitefly, *Aleurodicus rugioperculatus*, predator, *Pseudomallada astur*, consumption, functional response

INTRODUCTION

Rugose spiralling whitefly (RSW), *Aleurodicus rugioperculatus* was initially reported from Miami-Dade County, Florida, United States of America on gumbo limbo, *Burera simaruba* (L.) Sarg in 2009 as a pest (Stocks and Hodges, 2012). However, it was originally described from Belize in 2004 on coconut (Martin, 2004) where its natural population was reported. This whitefly is believed to have originated from Central America and distribution of this pest in Central and North America is limited to Belize, Mexico, Guatemala and the United States (Evans, 2008). In the continental United States, the first established population of rugose spiraling whitefly was reported from Florida in 2009 and since then its distribution range has expanded considerably within the state and subsequently, it has spread to 22 other countries in Central and South America. India is the only country in the Oriental region where the whitefly has been accidentally introduced. Initially, this whitefly was observed in several coconut farms in the Pollachi area of Coimbatore district, Tamil Nadu and first reported in Kottayam from Kerala during July–August 2016 (Sundararaj and Selvaraj , 2017). This pest has also been recorded from in Kadiyapulanka nurseries in coastal Andhra Pradesh during October-November, 2016. The possible entry to Andhra Pradesh may be through coconut seedlings transported from nurseries in Tamil Nadu and Kerala (Chalapathi Rao *et al*., 2020). Presently, infestation of RSW increased over the time and spread across the important coconut growing states in India and extending its host ranges at greater level which could be due to its polyphagous nature.

In Tamil Nadu, Elango and Nelson (2020) reported three predators *viz*., *Mallada desjardinsi, Chrysoperla zastrowi sillemi* and *Cryptolaemus montrouzieri* to be voraciously feeding on RSW and reducing its population. However , in coconut and oil palm plantations in East and West Godavari districts of Andhra Pradesh even after regular field releases of *C. zastrowi sillemi*, failed to establish successfully. However another neuropteran predator *P. astur* was found to feed and establish on RSW naturally under field conditions in various oil palm and coconut plantations (Kalidas, 2020) providing scope for biological control of RSW. Further *M. astur* (Banks) was reported as promising egg and early larval predator of coconut black headed caterpillar *Opisinsa arenosella* in interior Karnataka on coconut and palmyrah (Sujatha and Singh, 2003).

The potential of green lacewings as natural enemies for regulating the *A. dispersus* population was earlier

Table 1. Mean consumption rate and functional response of different instars of *P. astur* to different densities of RSW eggs

Stage	Prey offered *	Mean no. of prey consumed (Mean ± SE)	Consumption (%)
1st instar	40	37.5 ± 0.45	93.75
	80	75.8 ± 0.69	94.75
	120	101.7 ± 0.76	84.75
	160	120.1 ± 0.82	75.06
	200	144.5 ± 0.96	72.25
	CD (5%)	**2.15**	
2nd instar	50	47.5 ± 0.3	95.00
	100	96.5 ± 0.42	96.50
	150	134.2 ± 0.61	89.46
	200	159.00 ± 0.57	79.50
	250	188.8 ± 0.33	75.52
	CD (5%)	**1.38**	
3rd instar	60	59.3 ± 0.26	98.83
	120	116.7 ± 0.59	97.25
	180	174.5 ± 0.65	96.94
	240	198.0 ± 0.88	82.50
	300	210.8 ± 0.71	70.27
	CD (5%)	**1.86**	

* Mean of 10 replicates

reported by Geetha 2000; Boopathi *et al*., 2013; Boopathi *et al*., 2015. Further, *P. astur* feeding on RSW in Andhra Pradesh (Selvaraj *et al.,* 2016, Chalapathi Rao et *al.,* 2020) in Nalgari district of Assam (Chandrika Mohan *et al.,* 2018) in Tamil Nadu (Selvaraj *et al.,* 2016, Poorani and Thanigairaj, 2017, Elango *et al.,* 2019) and Kerala (Selvaraj *et al.,* 2016) on coconut and on RSW infesting oil palm (Selvaraj *et al.,* 2019 a) . This predator was also reported to feed on invasive whitefly *Aleurotrachelus atratus* Hempel (Selvaraj *et al.,* 2019b) .

Before using a predator in a biological control programme, it is essential to evaluate its predatory efficiency against the target species. As the information on the feeding potential and functional response of *P.astur* against *A. rugioperculatus* on coconut is lacking the present study was undertaken. The functional response can determine if a predator is able to regulate the density of its prey *i.e.,* it must show density dependence; the predator must respond to higher prey densities by consuming an increasing proportion of the available prey over a range of prey densities. The functional response curves may represent an increasing linear relationship (Type I), a decelerating curve (Type II), or a sigmoidal relationship (Type III). They result in a constant (I), decreasing (II) and increasing (III) rate of prey killing and yield density dependent, negatively density dependent and positively density dependent prey mortality, respectively. Predators or parasitoids that impose positively density dependence prey mortality (Type III) are supposed to potentially manage the prey population and could be considered as efficient bio control agents. (Fernandez-arhex and Corley, 2003)

MATERIALS AND METHODS

The production of predator *P. astur* was carried out in the bio-control lab, HRS, Ambajipeta. The egg masses of *P. astur* were collected from Kadiyapulanka nurseries, Andhra Pradesh and kept in plastic containers. After hatching, the grubs were fed with the surrogate host *C. cephalonia* sterilized eggs (produced as per standard methodology) in plastic pet jars (10cm x 15cm). About 0.2 cc of UV sterilized (15 watt ultraviolet tube light for 45 minutes) *C. cephalonia* eggs were sprinkled along with 50 eggs of *P. astur* and finely cut newspaper strips folded at 2 cm interval (30 cm x 2 cm).

After two days, the emerged grubs were collected and transferred individually with a fine camel hair brush into a small plastic vial with cap (3cm x 4.5cm) having pin size holes for aeration in which sterilized *C. cephalonica* eggs were also provided to facilitate the larval feeding

.After pupation of the grubs, the vials were uncapped and placed in basins covered with georgette black cloth and secured with rubber band till adult emergence. The emerged adults were carefully transferred with help of test tube into adult rearing jar (10cm x 15cm) where brown paper is placed inside the lid for harbouring the eggs laid. The egg cards were cut into small strips, with each strip containing 5- 10 eggs and utilised accordingly for the present study.

Functional response of *P. astur*

Functional response of different stages of *P. astur* to varying densities of RSW was studied in biological control laboratory of HRS., Ambajipeta . The first, second and third instar *P. astur* larvae were utilised for this study. Five densities (each replicated 10 times) of eggs of RSW were offered to the individuals of different stages of *P.astur* on coconut leaves in petri plates separately. The experimental arena consisted of a 5 cm coconut leaf disk with RSW spirals placed in a petri plate. The prey densities offered were 40, 80, 120, 160 and 200 for first instar; 50, 100, 150, 200 and 250 for second instar; 60, 120, 180, 240 and 300 for third instar; The experiments was carried out at constant temperatures of 27 ± 2 ºC and 60 ± 5 % RH and the data is presented as mean number of eggs fed and the consumption per cent at various egg densities offered is obtained by calculating the total number of eggs offered and number fed by various instars.

A logistic regression model was used (www.statsblue.com) to determine the shape of functional response by taking into consideration the proportion of prey eaten (Na/No) as a function of prey offered (No) (Juliano, 2001). The data were fitted to a polynomial function that describes the relationship between Na / No and No:

$$\frac{Na}{No} = \frac{\exp(Po + P1No + P2No\ 2 + P3No\ 3)}{1 + \exp(Po + P1No + P2No\ 2 + P3No\ 3)}$$

With Po, P1, P2, and P3 being the intercept, linear, quadratic and cubic coefficients, respectively and the parameters to be estimated , significant negative and positive linear coefficients (*i.e*. P1) from the regression indicate type II or type III functional response, respectively (Juliano, 2001). The sign of the linear coefficient in this model determines the type of functional response; significantly negative means type II (If $P1 < 0$, the proportion of prey consumed declines monotonically with the initial number of prey offered) and if the linear is significantly positive and the quadratic term is significantly negative, a type III response is inferred (If $P1 > 0$ and $P2 < 0$, the proportion of prey consumed is positively density dependent).

An experiment on feeding rate of *P.astur* on RSW was conducted under natural field conditions as the egg, nymph and pupal stages of RSW are relatively immobile, making it convenient to obtain a quantitative assessment of predation by *P. astur* in the field. The experiment was conducted in a 4 year old DX T (Ganga bondam x Philippines ordinary tall) coconut cross which has a total of thirteen leaves out of which RSW infestation was observed on 5 leaves . The infestation level was low with less than 10 spirals per leaf. Each infested leaf was considered as one replicate and laboratory-reared one day old larva of *P. astur* was released carefully at the rate one larva per leaf in vicinity of RSW spiral. The rate of feeding by the larva on RSW eggs was recorded at three hour interval and presented as mean number of eggs fed at this time interval.

RESULTS AND DISCUSSION

Functional response of *P. astur*

The data presented in table 1 revealed that the number of RSW eggs consumed by the 1st instar of *P.astur* at prey densities of 40, 80, 120 ,160 and 200 was 37.5, 75.8, 101.7, 120.1 and 144.5, respectively. The maximum proportion of the RSW eggs were consumed at the prey density of 80 (94.75%) and minimum proportion was consumed at prey density of 200 (72.25%). There were significant differences in consumption and as prey density increased the consumption rate by the 1st instar larva decreased .

The 2nd instar of *P.astur* consumed 48.7, 96.7, 131.1, 169.1 and 174.7 RSW eggs at the prey densities of 50, 100, 150, 200 and 250, respectively. The proportion of eggs consumed was significantly high (96.50%) at prey density of 100 eggs and minimum (75.52 %) at the highest prey density and proportion of prey consumed decreased with increasing prey density with significant differences in rate of feeding .

The mean number of RSW eggs consumed by 3rd instar of *P.astur* was 59.30, 116.7, 174.50, 198.0 and 210.8 number of RSW eggs at the prey densities of 60, 120, 180, 240 and 300, respectively. The proportion of eggs consumed was however significantly highest at the lowest prey density of 60 (98.83 %) and lowest at the highest prey density of 300 (70.27%) . In the present findings, the lower proportion of RSW eggs consumed at higher densities might be due to satiation of the predator at higher prey density. Kabissa *et al*. (1996) Nehare *et al.* (2004) and Huang and Enkegaard (2009) have reported

Table 2. Parameters of polynomial regression between proportions of prey consumed (Na/N) and initial prey density (N) of *P.astur*

Predator stage #	Parameter	Coefficient Mean ± SE	t- value	P value
First instar	P0 (Intercept)	-32.54 ± 1.294	-25.156	0.025
	P1 (Linear)*	2.22± 0.042	52.430	0.012
	P2 (Quadric)*	-0.01± 0.0	-32.767	0.019
	P3 (Cubic)	0	28.622	0.022
Second instar	P0 (Intercept)	-26.8 ±11.46	-2.337	0.257
	P1 (Linear)*	1.77± 0.299	5.908	0.106
	P2 (Quadric)*	-0.006± 0.002	-2.856	0.214
	P3 (Cubic)	0	2.211	0.270
Third instar	P0 (Intercept)	-9.64± 34.27	-0.281	0.825
	P1 (Linear)*	1.15± 0.746	1.551	0.364
	P2 (Quadric)*	-0.0001± 0.005	-0.029	0.981
	P3 (Cubic)	0	-0.503	0.702

prey offered in 10 replicates

*Positive linear (P1 > 0) and negative quadratic (P2 < 0) parameters indicate a Type III functional response

Table 3. Consumption rate of RSW eggs by *P.astur* under field conditions

Average no. of eggs observed / Spiral of RSW	Mean number of eggs fed by *P.astur* (I[st] instar) larva after				
	3 hours	6 hours	9 hours	12 hours	15 hours
46.25± 2.3	17.33 ± 2.40	29.33 ± 0.88	37.66 ± 2.33	42.33 ± 1.20	0.00

Values represented are Mean + standard error

that the prey consumption of lacewings increases with advancement in larval instars.

The data presented in Table 2 revealed that cubic polynomial fit between prey density offered (N) and proportion of prey consumed (Na/N) by all the stages of the predator resulted significant positive linear coefficients (1st instar: 2.22 ; 2nd instar: 1.77 ; 3rd instar: 1.15) and significant negative quadric coefficients (1st instar: -0.01; 2nd instar: -0.006; 3rd instar: -0.0001) confirming a Type III functional response for all the developmental stages of the predator. If P1(Linear) > 0 and P2 (Quadric) < 0, the proportion of prey consumed is positively density dependent, thus describing a type III functional response. The earlier studies by Sultan *et al.,* 2014 revealed that *Chrysoperla carnea* first instar exhibited a type II functional response while second and third larval instars revealed a type III functional response to different densities of sugar cane whitefly *Aleurolobus barodensis* .

Mehdi Hassanpour *et al*. (2009) reported that first and second larval instars of the predator *C. carnea* exhibited type II functional responses against the prey *Tetranychus urticae* however, the third instar larvae of the predator, showed type III functional response. Predators that exhibit type III functional response show positive density-dependence and are usually regarded as efficient biological control agents (Fernandez-arhex and Corley, 2003; Pervez, 2005).

The feeding activity by one day old larvae of *P. astur* in open field conditions revealed (Table 3) that out of 46.25 eggs present in a single spiral after three, six, nine and twelve hours 17.33, 29.33 , 37.66 and 42.33 eggs were consumed and by end of 15 hours the larva was found searching for eggs in new spirals in adjacent leaflets of the leaf indicating potentiality of this predator in the field too. The rate at which predators attack prey is to some extent dependent on prey density therefore, with increasing population of *A.rugioperculatus* the predator *P. astur* can have increasingly beneficial impact and if augmentative releases of *P.astur* is done it can give impetus to biological control of rugose spiralling whitefly.

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