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Functional Response of *Orius albidipennis* (Hemiptera: Anthocoridae) to the Two-spotted Spider Mite *Tetranychus urticae* (Acari: Tetranychidae)

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ABSTRACT

The objective of this study was to determine the functional response of the predator *Orius albidipennis* (Reuter) fed on egg of *Tetranychus urticae* Koch. We conducted a logistic regression of the proportion of prey consumed as a function of initial prey density to identify functional response types and used nonlinear least-squares regression and the random predator equation to estimate attack rates and handling times. Overall, all stages of *O. albidipennis* exhibited a type-I functional response to *T. urticae*. Whereas, attack rate (a) and handling time (T_h) of *O. albidipennis* female and male recorded 1.267, 0.828, 0.0122 and 0.0141 when offering eggs of *T. urticae*, respectively.

Key words: Functional response, *Orius albidipennis*, *Tetranychus urticae,* attack rate, handling time

INTRODUCTION

The two spotted spider mite *Tetranychus urticae* Koch. (Acari: Tetranychidae), considers one of the most important pests around the world in various ornamental and vegetable crops (Zaher, 1986; Childers, 1994; Takafuji *et al*., 2000; Zhang, 2003; Alatawi *et al*., 2005; Abd-Elhady and Heikal, 2011). On other hand, Insect predators are most effective regulators of pest populations (Cardoso and Lazzari, 2003; Padmalatha *et al*., 2003), which has led their increasing use in insect pest management programs (Wiedenmann and Smith, 1997; Riudavents and Castane, 1998). Due to, the current concerns to reduce the excessive use of chemicals insecticides for pest control, as well as to avoid increments in doses or utilization of highly toxic compounds (Gravena, 1989) biological control stands as a profitable alternative to the use of chemicals in the agroecosystem (Lester *et al*., 2000).

Predation is supposed to be one of the great biotic mortality factors reducing insect pest populations and using them in insect pest management programs has been receiving better consideration because of the recent need to reduce the exclusive apply of insecticides for pest control (Sarmento *et al*., 2007).

Members of the genus *Orius* (Heteroptera: Anthocoridae) are important predators of certain arthropods like aphids, aleyrodids, eggs and larvae of lepidopterous, thrips and mites (Pericart, 1972; Vacante *et al.*, 1997; Reitz *et al.*, 2006; Butler and O'Neil, 2007; Fathi and Nouri-Ganbalani, 2009). However, thrips and mites are believed to represent imperative diets for *Orius* spp. (Wright, 1994). Furthermore, several species of *Orius* have been received considerable attention in biological control programs due to their efficiency in number of agricultural ecosystems (Cocuzza *et al.*, 1997). Additionally the previous literatures stated that *Orius* spp. could effectively suppress spider mite populations in the field (Oatman and McMurthry, 1966; Du and Yan, 1995; Wittmann and Leather, 1997; Sanderson *et al.*, 2005; Rosenheim, 2005; Xu and Enkegaard, 2009). Of them, *Orius albidipennis* (Reuter) (Heteroptera: Anthocoridae) was found in the south Mediterranean basin, in the Canary Islands and East Africa (Salim *et al.*, 1987; Chyzik *et al.*, 1995; Fritsche and Tamo, 2000). In Egypt, *O. albidipennis* is very common in cultivated areas, especially in corn and cotton fields. It is generally establish in flowers of plants infested with thrips, lepidopteran eggs or other small arthropods. *O. albidipennis* does not occur in the field earlier than March, but its activity increases from April until the end of November (Tawfik and Atta, 1974; Zaki, 1989; Sobhi *et al.*, 2010).

Prior to the release of a natural enemy in a biological control program, it is essential to evaluate its efficiency under laboratory conditions. One useful method for evaluating the efficiency of a natural enemy is to assess of their behavioral characteristics including functional response and searching rates (Fathipour *et al.*, 2006; Bayoumy *et al.*, 2009). The relationship among the number of prey consumed per predator individual and prey density was defined as functional response (Solomon, 1949; Holling, 1959a, b). It plays a critical role in the perspective of prey-predator interactions and their ecological and evolutionary consequences (Tully *et al.*, 2005). Holling (1959a) identified three basic types of functional responses in general. The Type I response is characterized by a linear rise with a constant attack rate over all prey densities until satiation is reached. In the Type II response the attack rate decreases as prey density increases. Type III is represented by a sigmoid curve, where the attack rate increases with increasing prey density. Holling (1961) divided the functional response into several basic and subsidiary components. The attack rate (a) can be considered as a function of: (1) the reaction distance of the predator, i.e., the maximum distance at which the predator will react by attacking prey, (2) the speed movement of predator and prey and (3) the proportion of attacks that are successful. The handling time (T_h) can be considered to be a function of: (1) the time spent pursuing an individual prey, (2) the time spent investigating and probing each prey and (3) the time spent drilling each prey. The time as prey and predator exposure (T) can be considered to be a function of: (1) time in non-feeding activities and (2) time in feeding-related activities (i.e., T_h). The objective of this study was to investigate the functional response of *O. albidipennis* stages when preying on egg of *T. urticae* to improve our understanding of prey-predator interaction and get a better strategy for the biological control of *T. urticae* using *O. albidipennis*.

MATERIALS AND METHODS

Mite colony: The stock colony of *Tetranychus urticae* was collected from eggplant at the experimental farm, Ismailia Agricultural Research Station. *T. urticae* was collected from the same locations and host plants used for the collection of *Orius albidipennis*. The colony of *T. urticae* was kept on detached sweet potato branches kept with their upper part of the stem in contact with water in glass vials at 25±1°C, 50-80% RH and photoperiod was 14L/10D h.

Rearing of *Orius albidipennis*: A colony of *O. albidipennis* was established from nymphs and adults collected on eggplant plants (*Solanum melongena* L.) infested with *T. urticae* at the experimental farm, Ismailia Agricultural Research Station, Ismailia, Egypt. Adults and nymphs were maintained in plastic jars (10 cm diameter×20 cm height), which were covered with muslin that was held in place by rubber bands. Each jar was provided with sufficient quantities of *T. urticae* as a food supply, a piece of cotton that had been soaked in a 10% honey solution and bean pods (*Phaseolus vulgaris* L.) as an oviposition substrate. Bean pods with newly deposited eggs were removed and replaced daily, kept in previous jars. Jars were examined daily for hatching, after hatching nymphs were provided with *T. urticae* and small balls of foam to reduce cannibalism. Upon eclosion, adult males and females were sexed and placed in new plastic jars, provided with the same time of prey and oviposition substrates. Colonies were maintained at 26±1°C and 60±10% RH.

Functional response: The predator *O. albidipennis* larvae (4 h post molting) were collected from the colony and starved for 4 h in glass vials (7 cm×2 cm) containing small wet cotton with water without preys. Adult males and females 7 days old were collected in the same size of glass vials and starved 24 h before being used. Small discs 1.5 cm of sweet potato leaves harboring eggs of *T. urticae* was prepared and number of eggs was counted and put in Huffaker cells. Starved predators were singly transferred to modified Huffaker cells. *T. urticae* eggs were introduced as prey into modified Huffaker cell at six densities increased gradually to be synchronize with the developmental stage of the predators. Whereas, six prey densities of *T. urticae* were evaluated: 30, 40, 50, 60, 70 and 80 eggs for the fourth instar, fifth instar and adult males and females, respectively. Each predator individuals (larva and adult) was replicated ten times. After 24 h, numbers of consumed eggs of *T. urticae* were recorded.

Data analysis: The approach developed by Juliano (2001) was used to analyze the predator's functional response. Initially, the type (shape) of response was determined by seeing if the data pit a type I, II or III response, using a polynomial logistic regression of the proportion of prey consumed (Na/No) versus the initial number of prey offered (No) as follows:

$$\frac{N_a}{N_0}\frac{\exp(P_0+P_1N_0+P_2N_0^2+P_3N_0^3)}{1+\exp(P_0+P_1N_0+P_2N_0^2+P_3N_0^3)} \quad (1)$$

where, N_a is the number of prey consumed, N_0 is the initial number of prey density and P_0, P_1, P_2 and P_3 are the intercept, linear, quadratic and cubic coefficients, respectively. These parameters can be estimated using the CATMOD procedure in SAS (Juliano, 2001). The logistic regression was used to obtain the maximum likelihood estimates of parameters P_0 to P_3. The functional response type was determined by the sign of the linear coefficient from Eq. 1 and the significance of the parameters from the logistic model was evaluated by log likelihood tests. For a type I, the curve of Na/No versus No has a linear shape if the linear term from Eq. 1 was not significantly different from 0, a type I functional response was indicated , whereas a significant negative value indicated a type II response and a significant positive value indicated a type III (Juliano, 2001). The second part of the analyses used Holling disk equation (Holling 1959a) to estimate the parameter values of type I as follows:

$$H_a = \frac{a.H.T}{1+a.H.T_h}$$

where, H_a defines the number of prey attacked by a predator per time unit, a is attack rate of a predator, H is the original number of prey items offered to each predator at the beginning of the experiment, T is the total time of exposure time (1 day in this experiment) and T_h is handling time for each prey caught (proportion of the exposure time that a predator spends in identifying, pursuing, killing, consuming and digesting prey).

The parameters a (the rate of successful attack) and T_h (the time required to handle a prey item) were calculated using least-squares non-linear regression. Whereas, T_h values were used to calculate maximum attack rate as T/T_h (Hassell, 1978), this represent the maximal number of prey individuals that could be consumed by *O. albidipennis* during 24 h.

RESULTS AND DISCUSSION

Functional response, though an important tool, cannot only be attributed to report success and failures in biocontrol programs. For instance, other factors, such as intrinsic growth rates, host patchiness, predation and competition, host traits and environmental complexities (abiotic and biotic factors) also have a major influence on the efficiency of predator in managing the prey population (Pervez and Omkar, 2005).

The average number of *T. urticae* attacked by *O. albidipennis* increased with prey density during a 24 h period. Prey consumption by 4th, 5th, male and female of *O. albidipennis* increased 20.4 to 33.4, 23 to 38.4, 18.2 to 32.4 and 26 to 43.4 individual with increase in density of eggs of *T. urticae*, respectively. While, the proportion of killed preys by 4th, 5th, male and female of *O. albidipennis* decreased from 0.68 to 0.41, 0.76 to 0.48, 0.6 to 0.4 and 0.86 to 0.54 with increase in density of eggs of *T. urticae*, respectively (Fig. 1a, b). Decreasing in proportion of prey consume with increasing prey density is common for arthropods predator Holling (1961). Jalalizand *et al.* (2011) showed that functional response of *Orius niger niger* Take type II when fed on adult of *T. urticae* while it take type III when fed on egg of *T. urticae*. Gitonga *et al.* (2002) reported a functional Type I response curve of *O. albidipennis* preying on *Megalurothrips sjostedti* Trybom second instar larvae and adults at various densities.

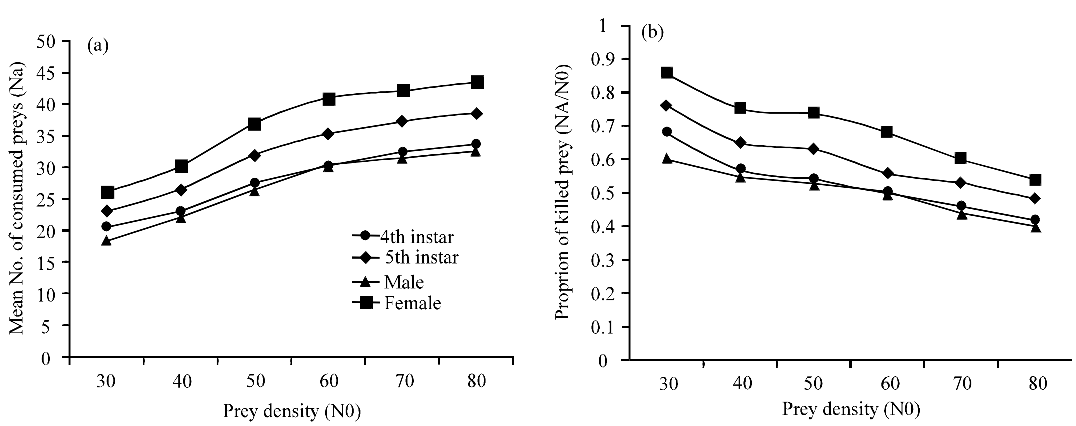

Fig. 1 (a, b): Observed functional response of *Orius albidipennis* 4th, 5th, male and female to *Tetranychus urticae* egg densities

Table 1: Results of logistic regression analyses, indicating estimates and standard errors of linear, quadratic and cubic coefficient for the proportion of prey eaten by *O. albidipennis* against initial prey number offered at 25°C

Stage of *O. albidipennis*	Coefficient	Estimate	SE	Chi-Square	p
4th instar	Intercept P_0	3.3104	1.7410	3.62	0.0572
	Linear P_1	-0.1370	0.1019	1.81	0.1787
	Quadratic P_2	0.00203	0.00189	1.15	0.2829
	Cubic P_3	-0.00001	0.000011	0.98	0.3214
5th instar	Intercept P_0	4.1124	1.8267	5.07	0.0244
	Linear P_1	-0.1596	0.1062	2.26	0.1327
	Quadratic P_2	0.00243	0.00196	1.54	0.2151
	Cubic P_3	-0.00001	0.000012	1.39	0.2377
Male	Intercept P_0	1.5700	1.3101	0.84	0.3586
	Linear P_1	-0.0608	0.1005	0.37	0.5449
	Quadratic P_2	0.000920	0.6220	0.00187	0.2400
	Cubic P_3	-5.83E-6	0.000011	0.28	0.5976
Female	Intercept P_0	5.1979	2.0525	6.41	0.0113
	Linear P_1	-0.1802	0.1178	2.34	0.1260
	Quadratic P_2	0.00263	0.00215	1.50	0.2211
	Cubic P_3	-0.00001	0.000013	1.35	0.2455

Data presented in Table 1 showed that the outcome of the logistic regression 4th, 5th instars, male and female to densities of eggs of *Tetranychus urticae* reflected a type I functional response, in all cases the sign of the linear term was negative and p>0.05 (Table 1).Whereas, the type of functional response can be determined based on the sign of the linear coefficient (Juliano, 1993). The type of functional response and estimated parameters for a natural enemy could be affected by some factors such as host plant. Temperature and type of prey or host and prey stages (Wang and Ferro, 1998; De Clercq *et al.*, 2000; Mohaghegh *et al.*, 2001). Xu and Enkegaard (2009) noticed that female of *Orius sauteri* (Poppius) reflected a type I functional response to densities of deutonymph of *T. urticae*. Whereas, Zamani *et al.* (2009) showed that the functional response of *O. albidipennis* to densities of female of *T. urticae* take type II. Although, Jalalizand *et al.* (2011) reported that *O. niger* female exhibited a type II and III functional response in their predation of *T. urticae* female and eggs, respectively.

The functional response data of *O. albidipennis* 4th, 5th, male and female to densities of eggs of *Tetranychus urticae* were successfully fitted to the Holling disk equation (Holling, 1959a) (Fig. 2, Table 2).

Attack rate and handling time were the parameters used to determine the magnitude of functional responses Pervez and Omkar (2005). The attack rate of *O. albidipennis* 4th and 5th was 1.613 and 1.148 whereas, male and female of *O. albidipennis* attack rate was 0.828 and 1.267 (Table 2).

Xu and Enkegaard (2009) showed that attack rate of *O. saurteri* female on *T. urticae* was 0.042. Whereas, Jalalizand *et al.* (2011) reported that attack rates of *O. niger* on both cucumber and strawberry for *T. urticae* female was 0.021 and 0.045, respectively. While, attack rates of *O. niger* on the same host for *T. urticae* egg was 0.001 and 0.003, respectively. On other hand, handling time is a good indicator of consumption rate and predator efficacy because it reflects the cumulative effect of time taken during capturing, killing, subduing and digesting the prey (Veeravel and Baskaran, 1997). Handling time (T_h) *O. albidipennis* 4th, 5th, male and female

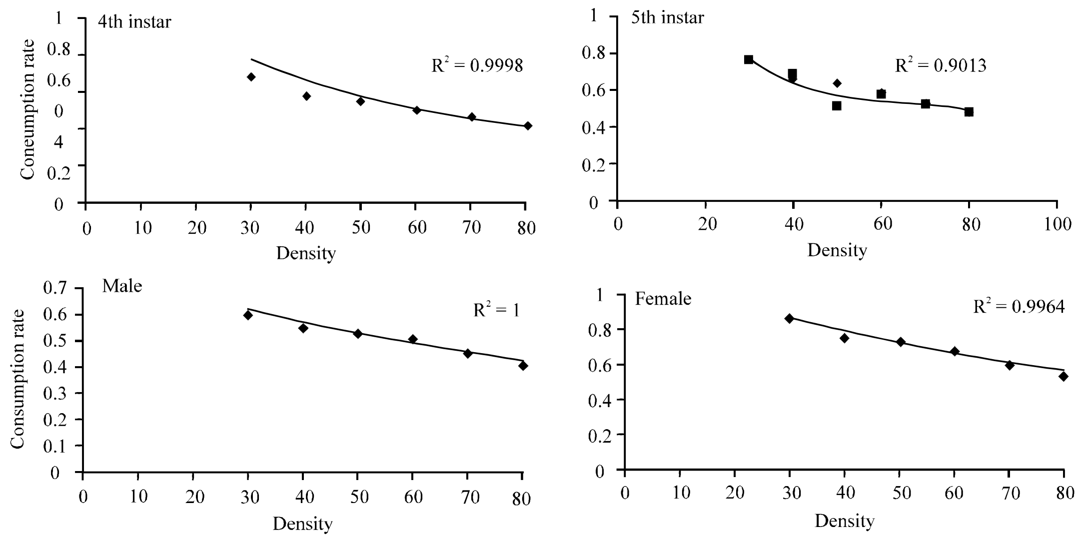

Fig. 2: Consumption rate of *Orius albidipennis* ,4th, 5th, male and female on eggs of *Tetranychus urticae* at 25±1°C, The fitted lines are predictions of the Holling (1959a) model

Table 2: Effect of *Tetranychus urticae* densities on the attack rate (a), handling time (T_h) and maximum number of consumption (T/T_h) on *O. albidipennis* derived from random predator equation

Stage of *O. albidipennis*	a	T_h	T/T_h
4th instar	1.613	0.0225	44.44
5th instar	1.148	0.0148	67.56
Male	0.828	0.0141	70.92
Female	1.267	0.0122	81.96

between 0.0122 and 0.0225. Whereas, The expected maximum consumption (T/T_h) of *O. albidipennis* 4th, 5th, male and female between 44.44 and 81.96 eggs per day of *T. urticae* (Table 2). Xu and Enkegaard (2009) reported that handling time (T_h) of *O. saurteri* female on *T. urticae* deutonymph was 1.217. Whereas, Zamani *et al.* (2009) showed that handling time (T_h) for the *O. albidipennis* when reared on *T. urticae* ranged between 0.005 to 0.012 days and the highest theoretical maximum predation rate was (80 adult).

In conclusion, the present study has improved our understanding of the *O. albidipennis* behavior to *T. urticae*. However, functional responses studies in small laboratory arenas have been criticized as being unrepresentative of natural conditions (Kareiva, 1990) and should be interpreted with care. We believe they may have some value as a first step in estimating predatory capacity but recommend that additional studies be conduct.

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