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Functional and Numerical Responses of *Stethorus gilvifrons* Mulsant Feeding on Strawberry Spider Mite, *Tetranychus turkestanii* Ugarov and Nikolski

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Abstract: Laboratory experiments were conducted to measure the functional and numerical responses of *Stethorus gilvifrons* Mulsant feeding on *Tetranychus turkestanii* Ugarov and Nikolski. Adult ladybirds were isolated singly for 24 h in 8 cm petri dishes with either 4, 8, 12, 24, 48 or 96 adult females of *T. turkestanii*. Results showed a typical type 3 functional response, with up to 65.2 preys attacked when 96 preys were provided. The rate of attack and handling time were 0.0012 and 0.415 (days), respectively. The number of eggs deposited by the predator depended on the density of the prey; up to maximum of 223.6 eggs female⁻¹ at prey density of 96 spider mites were recorded. No eggs were laid at densities of 4 and 8 prey/arena.

Key words: Functional response, numerical response, *Stethorus gilvifrons*, *Tetranychus turkestanii*, Coccinellidae, Tetranychidae

INTRODUCTION

Stethorus gilvifrons Mulsant (Coleoptera: Coccinellidae) is a biological control agent of the strawberry spider mite, *Tetranychus turkestanii* Ugarov and Nikolski (Acari: Tetranychidae), which is a serious pest of different crops and ornamentals in the southwestern of Iran and other parts of the world (Mossadegh and Kocheili, 2003; Kamali *et al.*, 2001; Jeppson *et al.*, 1975). Adult and larval stages of *S. gilvifrons* feed voraciously on different growth stages of *T. turkestanii* (Ahmed and Ahmed, 1989; Afshari, 1999). We present a study addressing the influences of prey densities on predation (i.e., functional response) and reproduction (i.e., numerical response) of *S. gilvifrons*. This is one part of a comprehensive evaluation of the biological control potential of *S. gilvifrons* and its interaction with *T. turkestanii*.

The functional response of a predator describes the relationship between the number of prey attacked and the prey density. The numerical response is defined as the change in the predator's reproductive output at varying prey densities. Functional response can be categorized into three types according to the shape of the curves (Holling, 1959). Predators that exhibit a type 1 functional response search for host randomly within a patch and attack prey at a constant rate, resulting in a linear relationship between the number of attacked preys and the prey density. The proportion of preys attacked by a

predator with a type 2 functional response decreases exponentially as the prey density increases. Type 3 functional response is described by an initial increase and subsequent decrease in the proportion of preys attacked with increasing prey density. Functional and numerical responses can be used to assess the potential impact of a predator on the population dynamics of its prey (Murdoch and Briggs, 1996). A type 2 functional response with a decelerating predation rate has the potential to destabilize prey-predator population dynamics due to an inverse density-dependent mortality of the prey (Hassell, 1978). In contrast, type 3 functional response, which incorporates density-dependent prey mortality, may stabilize the dynamics (Murdoch and Oaten, 1975). In addition, practitioners of inundative biological control may use functional response to estimate the appropriate number of biological control agents to be released in order to bring about an immediate reduction in pest number (Mills and Laca, 2004).

Although some bionomic studies on *S. gilvifrons* have been conducted by Haji-Zadeh *et al.* (1993) and Afshari (1999) no detailed study has reported on its functional and numerical responses to *T. turkestanii*. The objective of this study is to quantify the effect of spider mite density on prey consumption and egg production of *S. gilvifrons* for improving our understanding of prey-predator interaction. It could lead to the development of a better strategy for the biological control of *T. turkestanii* using *S. gilvifrons*.

MATERIALS AND METHODS

Stock culture of *T. turkestanii* and *S. gilvifrons*:

T. turkestanii and *S. gilvifrons* were collected in March 2007 from hollyhock (*Althea officinalis* L.) leaves at Shahid Chamran University, Ahwaz, Iran and were used to start the cultures of prey and predator. The stock colony of *T. turkestanii* was maintained on castor bean plants (cv. Ahwazy) grown from seeds and transplanted into compost in plastic pots (20 cm diameter). Infested plants were kept in wooden-framed rearing cage (120×60×60 cm) covered with white nylon mesh of 120 µm aperture. They were maintained at 25±1 °C, 65±5% RH, in the laboratory. The photoperiod was 16:8 (L:D) with illumination (4000 lux) provided from fluorescent lamps. Plants were kept in the cages until they were severely damaged by the spider mites, new plants being added when needed. After several generations, mites from the stock colony were used for the tests.

S. gilvifrons stock culture were maintained in a separate laboratory in above mentioned rearing cages using all stages of *T. turkestanii* as the food source on castor plants. Every weeks new *T. turkestanii*-infested castor plants were added to the cages. The condition of the laboratory was similar to those described above. All experiments were conducted at the Department of Plant Protection, Shahid Chamran University, Ahwaz, Iran.

The identity of *T. turkestanii* and *S. gilvifrons* were confirmed by K. Kamali and H. Hodek, respectively and voucher Specimens were deposited in the insect collection of Shahid Chamran University, Ahwaz, Iran.

Functional response: The experimental arenas consisted of a cowpea (*Vigna unguiculata* L.) leaf, floating upside down on a water-soaked polyurethan pad in a 8 cm diameter petri dish. Adult female strawberry spider mites (4, 8, 12, 24, 48, or 96) and coccinellids were individually transferred with a fine paint brush onto the leaf discs. The dishes were covered with lids ventilated with a 0.12 mm mesh. Five replications of each density were set up simultaneously. *S. gilvifrons* females have a high, constant daily egg production (Afshari, 1999). It was assumed that a predator's consumption rate is fully determined by its satiation level and not by its age. Thus, we standardized the condition of *S. gilvifrons* by starving it for 24 h at 25°C before its transfer to the leaf arena. Experiments lasted for 24 h in a growth chamber at 30±1 °C, 50-60±5 RH and 16: 8 (L:D). Observation were made with a stereomicroscope.

Numerical response: The numerical response experiments were carried out in Tashiro cages (Tashiro, 1967). The rate

of oviposition of *S. gilvifrons* was determined for the following prey densities: 4, 8, 12, 24, 48 and 96 female spider mites. At each density there were 5 leaves, each with one female ladybird (less than 24 h old). Tashiro cages were maintained in a growth chamber at 30±1 °C, 50-60±5 RH and 16:8 (L:D). Twenty four hours later the number of eggs deposited by each predator were recorded. Then the female predator were transferred to fresh leaves containing the same number of new preys. The numerical experiment was terminated with the natural death of the female predator.

Data analysis: Predation and reproduction data were first analysed by one-way analysis of variance (ANOVA) to test whether the number of prey attacked and the number of eggs laid differ for leaves with different initial prey density (SAS, 1997).

To simulate functional response, the random attack equation (Rogers, 1972) for predator were used.

$$N_a = N_t [1 - \exp(- (a' T_t P_t / 1 + a' T_h N_t))]]$$

(random attack equation)

Where:

exp = Base of natural logarithm,

N_a = No. of prey attacked,

P_t = No. of predators,

N_t = Prey density,

a' = Instantaneous rate of discovery or searching efficiency,

T_h = Handling time (expressed as day),

T_t = Total time and with $P_t = 1$ (one ladybird),

$T_t = 1$ (24 h),

N_a = Dependent variable,

N_t = Independent variable.

The data for the mean number of attacked preys per density were tested by non-linear least square techniques (SAS/STAT, NLIN-procedure (SAS, 1997)).

RESULTS AND DISCUSSION

Functional response: The ANOVA revealed significant effect of host density on predation rate. The mean number of preys consumed by each ladybird increased significantly as the number of prey increased (Table 1). The functional response curve obtained (Fig. 1) shows the variation in the consumption of females at different prey densities. The functional response was density dependent and corresponded to Holling's type 3 response curve. The functional response of *S. gilvifrons* increased from an average of 3.8 preys consumed per day

Table 1: Mean numbers and analysis of variance (ANOVA) of *Tetranychus turkestanii* adult females attacked by *S. gilvifrons* adult females on leaf with different prey density over a 24 h period at 30±1°C

N	Mean	Range	ANOVA			
			source	df	SS	p
4	3.8±0.20 ^c	3-4	Density	5	12860.00	<0.0001
8	6.8±0.80 ^c	4-8	error	24	849.20	
12	10.6±0.87 ^c	8-12				
24	22.2±0.58 ^b	20-23				
48	25.8±3.10 ^b	20-36				
96	65.2±5.57 ^a	48-79				

Means in the column followed by the same letter(s) were not significantly different at the 0.05 level when tested by LSD (1997)

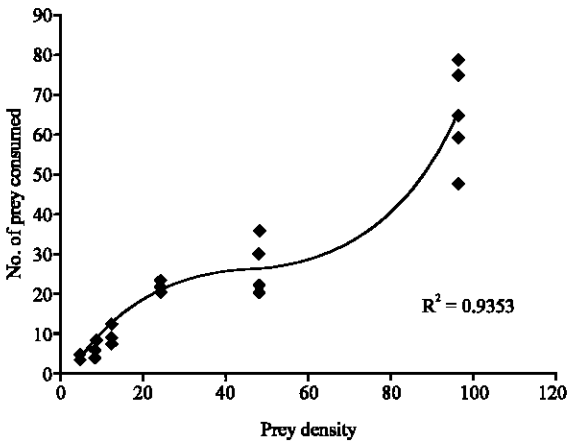


Fig. 1: Functional response of *Stethorus gilvifrons* adult females to the density of *Tetranychus turkestanii* adult females

at prey density of 4 adult mites per leaf to an average of 65.2 preys consumed per ladybird per day at a prey density of 96. From this type of response it can be seen that as prey density increases there is a proportional increase in prey consumption until an upper limit of about 65.2 adult mite/day is reached at density of 96 per leaf, indicating maximum prey consumption over a 24 h period.

The handling time (Th) and the instantaneous rate of discovery or attack coefficient (a') for *S. gilvifrons* feeding on different densities of female adult *T. turkestanii* were 0.415 and 0.0012, respectively. As a result, a female *S. gilvifrons* could consume a maximum of 57.82 adult mite per day (estimated maximum prey consumption = T/Th) which is consistent with the observed results.

Instantaneous rate of discovery (a') is the proportion of the total area searched by a predator/unit of searching time. It determines how rapidly the functional response curve approaches the upper plateau. Moreover, it is a function of (1) maximum distance at which the predator can perceive the prey, (2) speed of movement of predator and prey and (3) proportion of attacks that are successful (Holling, 1965, 1966). Handling time (Th) is the time

Table 2: Mean numbers and analysis of variance (ANOVA) of eggs laid by *S. gilvifrons* adult females feeding on different *T. turkestanii* densities at 30±1°C

N	Mean	Range	ANOVA			
			source	df	SS	p
4	0.0±0.00 ^d	-	Density	5	190689.9	<0.0001
8	0.0±0.00 ^d	-	error	24	2074.4	
12	8.2±0.33 ^d	6-12				
24	28.6±0.72 ^c	21-34				
48	83.4±0.80 ^b	75-90				
96	223.6±3.09 ^a	190-248				

Means in the column followed by the same letter(s) were not significantly different at the 0.05 level when tested by LSD (1997)

predator spend in identifying, chasing, killing, eating and other related time-consuming activities (Holling, 1959, 1965, 1966). The ratio between the total time that prey and parasitoids are exposed to each other and the handling time determines the maximum number of preys that can be attacked (upper asymptote). Handling time (Th) and attack rate (a') in this and other similar studies are used mainly for comparative purposes.

The type 3 functional response of *S. gilvifrons* reported by Haji-Zadeh *et al.* (1993) on *Panonychus ulmi* (Koch) is in accordance with these findings. However, type 2 functional response were also reported for *S. gilvifrons* by Mehr-Khou (2006) on *Tetranychus urticae* Koch and by Afshari (1999) on *Oligonychus sacchari* McGregor. In laboratory experiments, type 2 functional response were reported by Gotoh *et al.* (2004) for *Stethorus japonicus* Kamiya fed on eggs of *T. urticae* and by Hull *et al.* (1977) for *S. punctum* (LeConte) fed on European red mite.

Numerical response: Coccinellid fecundity was greatly affected by prey density. The mean and range of total egg production is shown in Table 2 and Fig. 2. Ladybirds reared on highest prey density (96 adult female) produced the most mean total eggs (223.6). ANOVA indicated significant overall density effects on mean total fecundity (F = 10.29; df = 5, 24; p = 0.0001).

Very few researchers have studied the numerical response of *Stethorus* ladybirds feeding on spider mites. Yigit and Uygun (1986) studied the numerical response of *Stethorus punctillum* Weise feeding on *Tetranychus viennensis* Zacher in laboratory conditions. Their result indicated a linear relationship between the prey density and number of eggs laid by ladybird which is similar to our findings.

The results obtained revealed that *S. gilvifrons* is a potential biocontrol agent against *T. turkestanii* because it has a sigmoid functional response resembling the type 3 curve of Holling (1959), considered to be the most stabilizing relationship. The results suggest that this coccinellid could play an important role in the biological

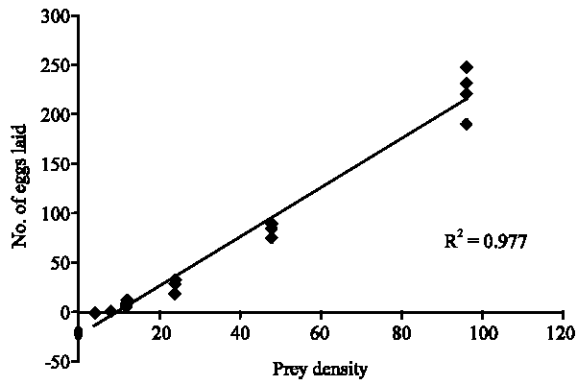


Fig. 2: Numerical response of *Stethorus gilvifrons* adult female to the density of *Tetranychus turkestanti* adult female

control of *T. turkestanti*. However in order to exploit this predator in biocontrol programs, more detailed research is required especially on the effect of predator density on functional and numerical response of *S. gilvifrons* and also the method and frequency of predator release and the number to be release each time.

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