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Functional Response of *Phytoseiulus persimilis* Athias-Henriot to the Two-Spotted Spider Mite Different Stages (Acari: Tetranychidae)

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ABSTRACT

The objective of this study was to determine the functional response of the predator *Phytoseiulus persimilis* Athias-Henriot fed on *Tetranychus urticae* koch larvae, nymphs and adults at different densities. A logistic regression of the proportion of prey consumed as a function of initial prey density was conducted to identify functional response types, and used nonlinear least-squares regression and the random predator equation to estimate attack rates and handling times. Overall, adult females *P. persimilis* exhibited a type 2 functional response to *T. urticae*. Whereas, attack rate (*a*) and handling time (T_h) of *P. persimilis* recorded 0.1722, 0.5034 and 0.4776 and 1.4699, 2.1133 and 3.051 when offering larvae, nymphs and adults of *T. urticae* respectively.

Key Words: Functional response, *Phytoseiulus persimilis*, *Tetranychus urticae*, Attack rate, Handling time.

INTRODUCTION

In Egypt, Rasmy and El-Laithy (1988) introduced the exotic predatory mite *Phytoseiulus persimilis* Athias-Henriot for biological control of *Tetranychus urticae* koch in green houses. Later on, many researchers have studied the feasibility of using this predator in biological control of *T. urticae* in greenhouse and open fields (El-Laithy, 1992; El-saiedy, 1999; El-saiedy, 2003; Osman, 2005 and Mahgoub, 2006) but the functional response of *P. persimilis* to different immatures stages of *T. urticae* has not been studied yet.

Functional response is defined as the relationship between the number of prey consumed per predator and prey density (Solomon, 1949 and Holling, 1959a, b). It plays a pivotal role in the understanding 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, then decreases towards satiation. Type II and III responses have generated the most ecological interest and most studies are confined to these two response types (Juliano, 2001). In terms of biological control, predators and parasitoids which exhibit the type III functional response, by showing positive density-dependent prey consumption, are usually regarded as efficient biological control agents (Pervez and Omkar, 2005). Nevertheless, there are some examples of natural enemies with the type II functional response model which have been successfully used as biological control agents (Luck, 1984; Hughes *et al.*, 1992; Fernandez-Arhex and Corley, 2003 and Mandour, *et al.*, 2006). Most arthropod predators possess type II response (Holling, 1961; Royama, 1971; Oaten & Murdoch, 1975 and Hassell, 1978). Holling (1961) divided the functional response into several basic and subsidiary components. The attack rate (a) can be considered to be 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-ovipositing activities; and (2) time in ovipositing-related activities (*i.e.*, T_h). The functional response of phytoseiid mites to the density of tetranychid mites has been investigated by many authors (Chant, 1961; Holling, 1974; Laing and Osborn, 1974; Santos, 1975; Everson, 1979; Sabelis, 1985; Badii *et al.* 1999; Cuellar *et al.*, 2001 and van Rijn *et al.*, 2005).

The objective of this study was to investigate the functional response of *P. persimilis* when preying on *T. urticae* to improve our understanding of prey-predator interaction and get a better strategy for the biological control of *T. urticae* using *P. persimilis*.

MATERIALS AND METHODS

I. Mite culture

Culture of the predatory mite *P. persimilis* was obtained from National Research Center, Cairo, Egypt.

Copulated adult females of *P. persimilis* were left to lay eggs on leaf discs of castor plants *Ricinus communis* placed on a moist cotton pad in Petri-disches, 15 cm in diameter at 25 ± 1 ^{0}C and 70±5% RH. and provided with the spider mites *T. urticae* as prey.

II. Functional response

Newly emerged adult females of *P. persimilis* were singly transferred to modified Huffaker cells and starved for 24hr (Sabelis, 1981; Overmeer, 1985). These closed cells were prepared with a piece of Plexiglas (8 · 4 cm and 5 mm of thickness) with a circular hole of diameter 1.5 cm in the middle of the plate. A second Plexiglas plate of the same size forms the base of the cell. On this second plate, a moistened filter paper was laid on which a piece of leaf of castor plants was placed upside down. The piece of Plexiglas with the hole was then placed on the leaf. A transparent coverslip closed the cell and all the pieces were held together with rubber bands. Therefore, each stage of *T. urticae* larva, nymph and adult was introduced as prey into modified Huffaker cells at densities of 4, 8, 12, 16, 20, 24, 28, 32, 36 and 40. Each density treatment was replicated ten times. After 24 hr, numbers of dead and living *T. urticae* were recorded.

Data analysis

The experimental data was analysed following Juliano (2001). The functional response type was determined by a logistic regression of the proportion of prey consumed as a function of initial prey number. Then, the data were fitted by an appropriate equation by the nonlinear least-squares regression. The polynomial equation was used to fit the data on the proportion of prey consumed:

$$\frac{N_a}{N_0} = \frac{\exp(P_0 + P_1 N_0 + P_2 N_0^2 + P_3 N_0^3)}{1 + \exp(P_0 + P_1 N_0 + P_2 N_0^2 + P_3 N_0^3)} \quad \text{----(1)}$$

Where, N_a is the number of prey eaten, N_0 is the initial number of prey, 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 equ. (1) and the significance of the parameters from the logistic model was evaluated by log likelihood tests. If $P1 < 0$, it describes a type 2 functional response. If $P1 > 0$ and $P2 < 0$, it presents a type 3 functional response (Juliano 2001) Because logistic regression analysis indicated that the present data fit the type 2 response, further analysis was restricted to the type 2 response.

In a second step, a nonlinear least squares regression of number of prey eaten vs. number offered was used to estimate and compare parameters of functional responses following the NLIN procedure in SAS. Functional response data were fitted to the random predaror equation equ. (2) Royama (1971) and Rogers (1972) to describe the type 2 functional response:

$$Na = N\{1 - \exp[-aT / (1 + aT_h N)]\} \quad \text{---------(2)}$$

where Na number of prey attacked per predator during experimental period T (24 h) ; N the initial prey density; a is the attack rate, T_h is the handling time of prey by the predator and T is the total time during which prey and predator are exposed to each other. 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 *P. persimilis* during 24 hr.

RESULTS AND DISCUSSION

The average number of *T. urticae* devoured by *P. persimilis* varied with prey stage, but increased with prey density during a 24 hr period. Prey consumption by *P. persimilis* increased from 4 to 20, 4 to 28 and 4 to 28 individual with increase in density of larvae, nymphs and adults of *T. urticae*, respectively. On the other hand, the proportion of killed preys by *P. persimilis* decreased from 1 to 0.03, 1 to 0.13 and 1 to 0.21 with increase in density of adults, nymphs and larvae of *T. urticae* respectively. (Fig. 1 A&B). Decreasing in proportion of prey consume with increasing prey density is known for arthropod predator (Holling, 1961).

Data presented in table (1) showed that the outcome of the logistic regression of adult female *P. persimilis* to larvae, nymphs and adults of *T. urticae* reflected a type II functional response, in all cases the sign of the linear term was negative (Table 1).

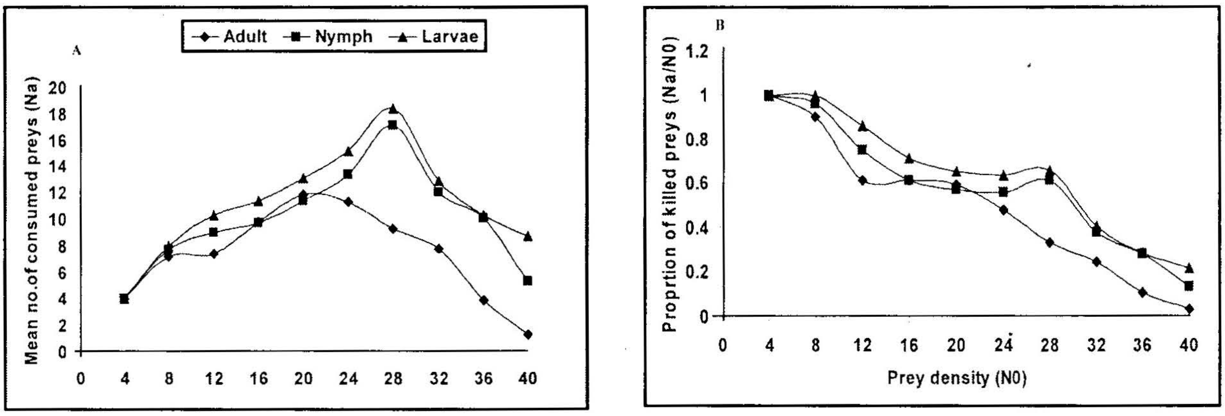

Fig. (1 A & B): Observed functional response of *Phytoseiulus persimilis* females to densities of larvae, nymphs and adults of *Tetranychus urticae*.

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 *P.persimilis* against initial preys number offered at 25 ^{0}C.

Stage	Coefficient	Estimate	S. E	χ^2	P
Larva	Intercept P_0	11.7790	1.4634	64.79	<0.0001
	Linear P_1	-1.3059	0.1793	53.03	<0.0001
	Quadratic P_2	0.0479	0.00694	47.52	<0.0001
	Cubic P_3	-0.00058	0.000085	45.81	<0.0001
Nymph	Intercept P_0	8.2089	1.0659	59.31	<0.0001
	Linear P_1	-0.9801	0.1402	48.89	<0.0001
	Quadratic P_2	0.0397	0.00577	47.28	<0.0001
	Cubic P_3	-0.00054	0.000075	52.05	<0.0001
Adult	Intercept P_0	4.9002	0.8295	34.90	<0.0001
	Linear P_1	-0.5534	0.1199	21.31	<0.0001
	Quadratic P_2	0.0230	0.00538	18.35	<0.0001
	Cubic P_3	-0.00036	0.000075	23.16	<0.0001

A significant negative estimate for the parameter P_1 indicate that the slope of the functional response curve is declining, thus a type II functional response

Whereas, the type of functional response can be determined based on the sign of the linear coefficient: negative for type II, positive for type III (Juliano, 1993). Type II functional response is the most common functional response of the phytoseiid species to an increasing density of spider mites (Fernando and Hassell, 1980; Sabelis, 1985; Shipp and Whitfield, 1991 and Skirvin and Fenlon, 2003). Chant (1961) reported a Type II curve for *P. persimilis* on *T. urticae*. Laing and Osborn, 1974; Ryoo 1996 and Landeros *et al.*, 2001 also, reported a functional Type II response curve for *P. persimilis* feeding on *T. urticae* adults.

The functional response data of *P. persimilis* on larvae, nymphs and adult females of *T. urticae* were successfully fitted to the Royama (1971) and Rogers (1972) equation (Fig. 2, Table 2). The attack rate of *P. persimilis* increased from 0.17 on larvae to 0.50 on nymphs but declines on adult female of *T. urticae* to 0.47. Whereas, handling time (T_h) of *P. persimilis* was 1.4699, 2.1133 and 3.051 when offering larvae, nymphs and adults of *T. urticae*, respectively. The expected maximum consumption (T/T_h) of *P. persimilis* was 16.32 larvae, 11.36 nymphs and 7.90 adults per day of *T. urticae*.

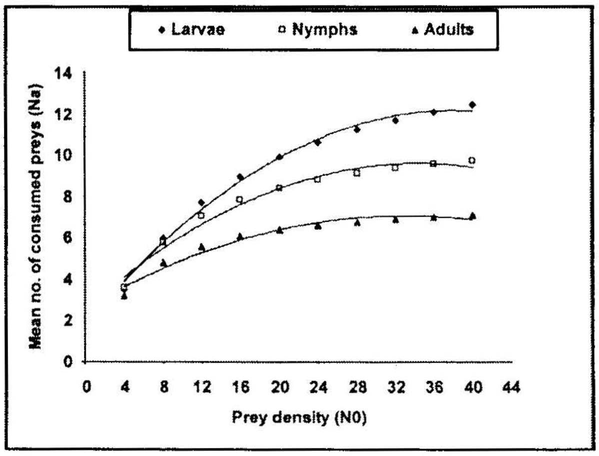

Fig. (2): Functional responses of *Phytoseiulus persimilis* on adults, nymphs and larvae of *Tetranychus urticae* at 25±1 ^{0}C, the fitted lines are predictions of the Rogers (1972) model.

The level of functional responses is affected by the life stages of prey supplied. For example, Fernando and Hassell (1980) showed that the maximum number of *T. urticae* consumed by *P. persimilis* decreased in the order: egg, larva, protonymph and deutonymph. Still further, phytoseiid mites very seldom prefer to feed on adult mites but most often they feed on immature stages (Sabelis, 1985). Blackwood *et al.* (2001) reported that adult females of *P. persimilis* preferred *T. urticae* eggs over the larvae. In contrast, Popov and Kondryakov (2008) reported that adult females of *P. persimilis* consumed more males of *Tetranychus*

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

Stages	*A*	Asymptotic 95 % CI		T_h	Asymptotic 95 % CI		T/T_h
		lower	upper		lower	upper	
Larva	0.17±0.04	0.07	0.26	1.46±0.09	1.28	1.65	16.32
Nymph	0.50±0.48	0.25	1.46	2.11± 0.13	1.83	2.38	11.36
Adult	0.47±0.71	0.11	1.90	3.03±0.26	2.50	3.56	7.90

spp. than the eggs or females. These contrasting results may be related to differences in experimental design and number of prey provided. Fernando and Hassell (1980) reported that the search rate and the handling time of females of *P. persimilis* preying on eggs of *T. urticae* were 1.69 and 0.87 (h), respectively. It should be realized that predation by phytoseiid mites is generally not limited by handling time but by digestion rate (e.g. Sabelis, 1985).

The results showed that *P. persimilis* females were more effective at low different prey stages densities. Also, increase predation rate and short handling time of *P. persimilis* females as function of *T. urticae* larvae, guide us to release *P. persimilis* early on low prey densities and the best time when the prey is in larval stage.

REFERENCES

El-Laithy, A. Y. M. 1992. Some aspects on the use of the predaceous mite *Phytoseiulus persimilis* Athias – Henriot. For biological control of the two spotted spider mite *Tetranychus urticae* koch in greenhouses in Egypt. J. Plant Dis.,Prot. 99: 93-100.

El-saiedy, S. M., 1999. Integrated control studies on *Tetranychus urticae* koch on soya bean plant. M. Sc. Thesis, Fac. Of Agric. Minufiya Univ.

El-saiedy, S. M., 2003. Integrated control studies on red spider mite *Tetranychus urticae* koch on strawberry plants. Ph. D. Thesis, Fac. of Agric. Cairo Univ.

Badii, M.H.; McMurtry, J.A. and Flores, A. E., 1999. Rates of development, survival and predation of immature stages of *Phytoseiulus longipes* (Acari: Mesostigmata: Phytoseiidae). Exp. Appl. Acarol., 23:611–621.

Blackwood, J.S. ; Schausberger, P. and Croft, B.A., 2001. Prey stage preferences in generalist and specialist phytoseiid mites (Acari: Phytoseiidae) when offered *Tetranychus urticae* (Acari: Tetranychidae) eggs and larvae. Enviro. Entom., 30, 1103–1111.

Chant, D.A. 1961. The effect of prey density on prey consumption and oviposition in adults of *Typhlodromus occidentalis* (Nesbitt) in the laboratory. Can. J. Zool., 39:311–315.

Cuellar, M.E.; Calatayud, P.; Melo, E.L.; Smith, L. and Bellotti, A.C. 2001. Consumption and oviposition rates of six phytoseiid species feeding on eggs of the cassava green mite *Mononychellus tanajoa* (Acari: tetranychidae). Fla. Entomol., 84:602–607.

Everson, P. 1979. The functional response of *Phytoseiulus persimilis* (Acarina: Phytoseiidae) to various densities of Tetranychus urticae (Acarina:Tetranychidae).Can Entomol., 111:7–10

Everson, P. 1980. The relative activity and functional response of *Phytoseiulus persimilis* (Acarina: Phytoseiidae) and *Tetranychus urticae* (Acarina: Tetranychidae): the effect of temperature. Can. Entomol., 112:17–24.

Fernando, M. and Hassell, M. 1980. Predator–prey responses in an acarine system. Res. Popul. Ecol., 22: 301–322.

Fernández-Arhex, V. and Corley, J. C. 2003. The functional response of parasitoids and its implications for biological control. Biocontrol Science and Technology, 13: 403–413.

Hassell, M.P., 1978. The Dynamics of Arthropod Predator Prey Systems Monographs in Population Biology 13, pp: 1–237 Princeton, N.J: Prinnceton University Press.

Holling, C. S. 1959a. The components of predation as revealed by a study of small-mammal predation of the European pine sawfly. Can. Entomol., 91:293–320.

Holling, C. S. 1959b. Some characteristics of simple types of predation and parasitism. Can. Entomol., 91:385– 398.

Holling, C. S. 1961. Principles of insect predation. Annl. Rev. Entomol., 6: 163–183.

Hughes, R. D.; Woolcok, L.T. and Hughes, M. A. 1992. Laboratory evaluation of the parasitic Hymenoptera used in attempts to biologically control aphid pests of crops in Australia. Entomologia Experimentalis et Applicata. 63: 177–185.

Jackson, G. J. and Ford, J. B. 1973. The feeding behaviour of *Phytoseiulus persimilis* (Acarina: Phytoseiidae), particularly as affected by certain pesticides. Ann. Appl. Biol., 75:165–171.

Juliano, S. A., 1993. Nonlinear curve fitting: predation and functional response curves. In: Design and Analysis of Ecological Experiments. Ed. by SCHEINER, S. M.; GUREV- ITCH, J. New York: Chapman & Hall, 159-182.

Juliano, S. A., 2001. Nonlinear curve-fitting: predation and functional response curves. In: Scheiner SM, Gurevitch J (eds) Design and analysis of ecological experiments, 2nd edn. Oxford University Press, New York, pp 178–196

Landeros, J.; Rodriguez, S.; Badii, M.H.; Cerda, P.A. and Flores, A. E., 2001. Functional response and population parameters of *Phytoseiulus persimilis* Athias-Henriot on *Tetranychus urticae* Koch. Southwest Entomologist, 26:253–257.

Laing, J. E. and Osborn, J.A., 1974. The effect of prey density on the functional and numerical responses of three species of predatory mites. Entomophaga, 19:267–277.

Luck, R.F., 1984. Principles of arthropod predation. Ecological Entomology (eds. C.B. Huffaker & R.L. Rabb), pp. 497 - 530. Wiley Interscience, New York.

Mandour, N.S.; El-Basha, N.A. and Liu, T.X., 2006. Functional response of the ladybird, *Cydonia vicina nilotica* to cowpea aphid, Aphis craccivora in the laboratory. Insect Sci., 13: 49–54

Oaten, A. and Murdoch, W.W., 1975. Functional response and stability in predator-prey systems. American Nat., 109: 289–298

Overmeer, W. P. J., 1985. Rearing and handling. In: Helle, W., Sabelis, M.W. (Eds.), Spider Mites: Their biology, natural enemies and control. World Crop Pests. Elsevier.

Pervez, A. and Omkar, J. BE., 2005. Functional responses of coccinellid predators: an illustration of a logistic approach. Journal of Insect Science, 5: 1–6.

Popov, S.Y.and Kondryakov, A.V., 2008. Reproductive tables of predatory phytoseiid mites (*Phytoseiulus persimilis, Galendromus occidentalis* and *Neoseiulus cucumeris*). Entomological Review, 88: 658–665.

Rasmy, A. H. and El-Laithy, A. Y. M., 1988. Introduction of *Phytoseiulus persimilis* for the two spotted spider mite control in greenhouses in Egypt. (Acari: Phytoseiidae, Tetranychidae). Entomophaga, 33: 435- 438.

Ryoo, M. I., 1996. Influence of the spatial distribution pattern of prey among patches and spatial coincidence on the functional and numerical response of *Phytoseiulus persimilis* (Acarina: Phytoseiidae). J. Appl. Entomol. 120:187–192.

Royama, T. 1971. A comparative study of models for predation and parasitism. Res. Popul. Ecol., 1: 1–91.

Sabelis, M.W., 1981. Biological control of two-spotted spider mites using phytoseiid predators. Part I: modelling the predator-prey interaction at the individual level. Agricultural Research Reports, Pudoc, Wageningen, p. 242

Sabelis, M. W., 1985. Predator–prey interaction: predation on spider mite. In: Helle W, Sabelis MW (eds) World crop pests 1B. spider mites: their biology natural enemies and control. Elsevier, Amsterdam,: 103–129

Santos, M. A. 1975. Functional and numerical responses of the predatory mite, *Amblyseius fallacis*, to prey density. Environ. Entomol., 4:989–992

Shipp, J. and Whitfield, G., 1991. Functional response of the predatory mite, *Amblyseius cucumeris* (Acari: Phytoseiidae), on western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae). Environ. Entomol., 20: 694–699.

Skirvin, D. J. and Fenlon, J.S., 2003. The effect of temperature on the functional response of *Phytoseiulus persimilis* (Acari: Phytoseiidae). Exp. Appl. Acarol., 31, 37–49.

Solomon, M. E. 1949. The natural control of animal populations. J. Anim. Ecol., 18:1–35.

Tully, T.; Cassey, P. and Ferriere, R., 2005. Functional response: rigorous estimation and sensitivity to genetic variation in prey. Oikos, 111:479–487.

Van Rijn P. C. J., Bakker F. M., Van der Hoeven W. A. D., Sabelis M. W., 2005. Is arthropod predation exclusively satiation-driven? Oikos, 109:101–116.