

**الاستجابة الوظيفية للتربس المفترس *Scolothrips*
(Thysanoptera: Thripidae) *sexmaculatus*
للأكاروس العنكبوتي ذي البقعتين *Tetranychus*
(Acari : Tetranychidae) *urticae***

مروة الصلاحي⁽¹⁾ لؤي أصلان⁽²⁾ عبد النبي بشير⁽³⁾

المخلص

استخدمت طريقة الاختبار الحيوي للقرص الورقي في تقييم فاعلية التربس المفترس للأكاروس (*Thysanoptera: Thripidae*) *Scolothrips sexmaculatus* Pergande. كعامل مكافحة حيوية للأكاروس العنكبوتي ذي البقعتين *Tetranychus urticae* Koch. (Acari: Tetranychidae). أظهر المفترس استجابة الوظيفية من النموذج الثالث (Sigmoid) Holling III عند خمس كثافات مختلفة من بالغات الفريسة *T. urticae* (5، 10، 20، 40، 80). بناءً على معادلة المفترس Holling فقد كانت قيمة معدل الهجوم (a) وزمن التناول (T_h) 0.07 / ساعة و 0.88 ساعة على التوالي. ازدادت فاعلية المفترسات في البحث عن الفريسة بزيادة كثافة الفريسة، حيث ارتفعت النسبة المئوية للموت مع زيادة كثافة الفريسة في البداية، ثم انخفضت مع انخفاض الكثافة. بيّنت نتائج هذه الدراسة إمكانية استخدام هذا المفترس *S. sexmaculatus* في برامج مكافحة الحيوية للأكاروس *T. urticae*، ومع ذلك لا بد من إجراء العديد من الدراسات الحقلية لدعم النتائج المخبرية.

الكلمات المفتاحية: مكافحة الحيوية، *Scolothrips sexmaculatus* ، *Tetranychus urticae*، الاستجابة الوظيفية.

(1) أستاذ، قسم وقاية النبات، كلية الزراعة، جامعة دمشق، دمشق، سورية.

Basherofecky@yahoo.com , Louai@arabscientist.org

(2) (3) دكتور باحث، قسم وقاية النبات، الهيئة العامة للبحوث العلمية الزراعية، دمشق، سورية.

Functional response of predatory thrips *Scolothrips sexmaculatus* (Thysanoptera: Thripidae) preying on *Tetranychus urticae* (Acari : Tetranychidae) to the two-spotted spider mite

Marwa Al-Salahi⁽¹⁾

Louai Asslan⁽²⁾

Abedlnabi Basheer⁽³⁾

Abstract

A leaf disc bioassay was employed to evaluate the efficiency of an acarophagous thrips, *Scolothrips sexmaculatus* Pergande. (Thysanoptera: Thripidae) as a biocontrol agent to two-spotted spider mite *Tetranychus urticae* Koch. (Acari: Tetranychidae). The predator exhibited Holling- III type functional responses (Sigmoid) when it was offered *T. urticae* adults at five densities (5, 10, 20, 40 and 80). Based on the random predator equation, the estimated attack rate (a) and handling time (T_h) were $0.07h^{-1}$ and 0.88 h respectively. The predators increase their search activity with increasing prey density and mortality first increases with prey increasing density, and then declines. The results of this study revealed that *S. sexmaculatus* could be used in the biological control programs of *T. urticae*. However, further field studies are needed to verify this hypothesis.

Keywords: Biological control, *Scolothrips sexmaculatus*, *Tetranychus urticae*, functional response.

(1) Dr. Res., Department of plant protection, General commission for scientific agricultural research, Damascus, Syria. . marwaalsalahi@yahoo.com

(2) (3) Prof., Department of plant protection, Faculty of agriculture, Damascus University, Damascus, Syria. Basherofecky@yahoo.com , Louai@arabscientist.org

INTRODUCTION

The two spotted spider mite, *Tetranychus urticae* Koch. is one of the most important pests of more than 900 host plants all over the world (Modarres *et al.*, 2011), such as various species of orchard trees, field crops, ornamental plants and greenhouse plants. It induces serious damage by direct feeding (Duso *et al.*, 2008), reducing photosynthetic activity and leaf abscission in severe infestation (Alzoubi and Cobanoglu, 2008) which described this pest as a serious pest of at least 150 economically important plants. Pesticides are the conventional method of controlling *T. urticae*. However, the wide use of pesticides is associated with problems such as pest population develops resistance to acaricides and the fruits have chemicals residues (Garsia-Mari and Gonza'lez-Zamora, 1999). Biological control is a safe alternative method in which natural enemies are used for controlling economically important pests (Kishimoto and Takagi, 2001). One important method for assessing the efficacy of natural enemies is the study of their foraging behavior including functional response (Fathipour *et al.*, 2006). Functional response is the number of prey successfully attacked per predator as a function of prey density (Solomon, 1949). It describes the way a natural enemy responds to the changing density of its prey and it is a commonly measured attribute of natural enemies. Several species of predatory thrips of the genus *Scolothrips* (Thysanoptera: Thripidae), especially the six-spotted thrips *Scolothrips sexmaculatus*, have been investigated for their potential to control spider mites, (Coville and Allen, 1977 and Gilstrap and Oatman, 1976). *S. sexmaculatus* is common in bean, cucumber and eggplant fields and has been demonstrated to be an important predator of several spider mite species, with a seasonal abundance correlated with that of the pest (Coville and Allen, 1977). One of the most important methods to assess the efficacy of natural enemies is studying the behavioral characteristics, including foraging behavior. Studying predator behavior is an important key to understand how the predators live, and how they influence the population dynamics of their prey (Dixon, 2000). It is thus a necessary prerequisite for the selection of natural enemies for biological control programs and for the evaluation of their performance after releasing (Van Driesche and Bellows, 1996). There are many factors influencing the functional response of a predator, especially the temperature of the environment (Gitonga *et al.*, 2002, Enkegaard, 1994). Only a few investigators have examined the relationship between

temperature and functional response of the predators of the genus *Scolothrips* including *S. takahashii* (Ding-Xu *et al.*, 2007). Functional response of a predator is a key factor regulating the population dynamics of predator-prey systems. It describes the rate at which a predator kills its prey at different prey densities and can thus determine the efficiency of a predator in regulating prey populations (Murdoch and Oaten 1975). This is further supported by plotting the number of prey killed against the number of prey available and analyzing a continuum of patterns, which ecologists have delimited into three types (Holling 1959a, 1965). The functional response curves may represent an increasing linear relationship (Type I), a decelerating curve (Type II), or a sigmoidal relationship (Type III). This could further be simplified in terms of density dependence. That is, 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. The aim of the present research was to study the functional response of the predator *S. sexmaculatus* to the various densities of two-spotted spider mite *T. urticae* under laboratory conditions.

Materials and Methods

Laboratory studies were conducted at the General Commission for Scientific Agricultural Research (GCSAR), Damascus countryside, Syria.

Mite culture

A colony of the two-spotted spider mite *T. urticae* was initiated using individuals originally collected from bean (*Phaseolus vulgaris* L. cv. Tema) fields in Damascus countryside, Syria. A mass culture of the mite was maintained on potted bean plants at $25\pm 1^{\circ}\text{C}$, $60\pm 10\%$ RH and a photoperiod of 16:8 (L:D) hrs for more than one year.

Culture of the predator

S. sexmaculatus individuals, found associated with *T. urticae*, were also collected from bean plants at the same location and transferred to the laboratory. The predatory species was identified, with the aid of a binocular. Predator's culture was maintained for six months before been used in experiments (Parvin *et al.*, 2010).

Experimental Design

Bean plants, free of pesticides, were grown under laboratory conditions,

leaf discs (30 mm diameter), without major veins, were cut and served as tested arena, according to the modified leaf-island method (Sengonca and Gerlach, 1983), the experimental arenas placed on moist cotton in Petri plates (9 cm diameter), cotton was kept oversaturated with water to prevent the possible escape of mite and predator, adult of *T. urticae* were transferred to healthy bean leaves placed upside down on a moist cotton pad, which was laid on the top of a sponge (0.5 inch thick) in plastic trays (42 x 30 x 6.5 cm). Water was added to the rearing unit when necessary to prevent the leaves' dryness.

Experiments on the functional response to adult females and the response of predator to prey density were conducted at 25° C and 75 ± 5% RH. The photoperiod for all experiments was 14:10 L:D. Consumed prey in the arena of experiments on functional response were removed at each observation and replaced with new ones to maintain ample food supply. All experiments were conducted for seven consecutive days, and the mean values of all replications on each day were summed and averaged to get the final results of the experiment. Data from the first day of each experiment were excluded from the final analysis to dismiss the possibility of unusual response of the sample of predator thrips to an abrupt life stage of the prey and prey density from that of stock colony.

Adult females of *S. sexmaculatus* were transferred from the stock colony on to an excised bean leaf with prey mites and allowed to lay eggs for 12 hours. Then, adult were removed, and the eggs of *S. sexmaculatus* were allowed to complete their post-embryonic development on the leaf. After mating, females were separated and used in the bioassays when they were 6 days old after hatching. They were starved for 24 hours on bean leaves arranged as described for the rearing of predator. Each leaf disc was then inoculated with 5, 10, 20, 40 and 80 adult females of *T. urticae*, and a single gravid female of *S. sexmaculatus* was introduced on each leaf disc.

Each prey density should be replicated to get sufficient accuracy. More experiments should be done with low prey density than with high prey density because the error of mortality estimates depends on the total number of prey. Experiments are usually set for a fixed time interval. Experiments were conducted at 25°C. The number of prey consumed per predator thrips was recorded every 24 hours for seven consecutive days.

Data analysis

Functional responses were determined by fitting the data to the Holling disc equation (Holling, 1959 a,b), and can transformed to a linear form:

$$H_a = \frac{a \cdot H \cdot T}{1 + a \cdot H \cdot T_h} \quad \longrightarrow \quad \left(\frac{1}{H_a}\right) = \left(\frac{1}{a}\right) \cdot \left(\frac{1}{H \cdot T}\right) + \left(\frac{T_h}{T}\right)$$

$$y = \alpha \cdot x + \beta$$

Where H_a is the number of successful attacks per predator during a specific time period (T), which in this is case 1 day, H is the initial density of the prey, and a and T_h are the rate of successful attacks and the time required to handle the prey respectively. Handling time is defined as the time that the predator requires to pursue, kill, and digest the prey (Holling, 1963). The parameters a and T_h were calculated using a linear regression technique where $1/H_a$ was regressed on $1/H$, a is the reciprocal of the slope and T_h is the intercept. The a/T_h value indicates the effectiveness of predation. Maximum predation rate (K) was calculated as T/T_h .

Consumption rate of a predator is limited by model of functional response because even if prey is so abundant that no time is needed for search, a predator still needs to spend time on prey handling. Total time equals to the sum of time spent on searching and time spent on handling:

$$T = T_{\text{search}} + T_{\text{handling}}$$

Results and Discussion

The predator *S. sexmaculatus* exhibited a type III functional response when it was offered *T. urticae* adults at five densities 5, 10, 20, 40 and 80 (Table 1), and by a Sigmoid curve prey mortality can increase with increasing prey density to a plateau, the relationship can be expressed by the equation $Y = 14.692 X + 0.1099$ (Figure 1).

Table (1): Relationship between density of *T. urticae* and total prey killed by *S. sexmaculatus*

prey density H	No. of replications	Total prey killed	Average no. of prey killed Ha	1/Ha	1/(HT)
5	20	46	2.3	0.434	0.025
10	10	25	2.5	0.400	0.0125
20	5	28	5.6	0.179	0.0063
40	3	23	7.7	0.129	0.0031
80	3	25	8.3	0.120	0.0016

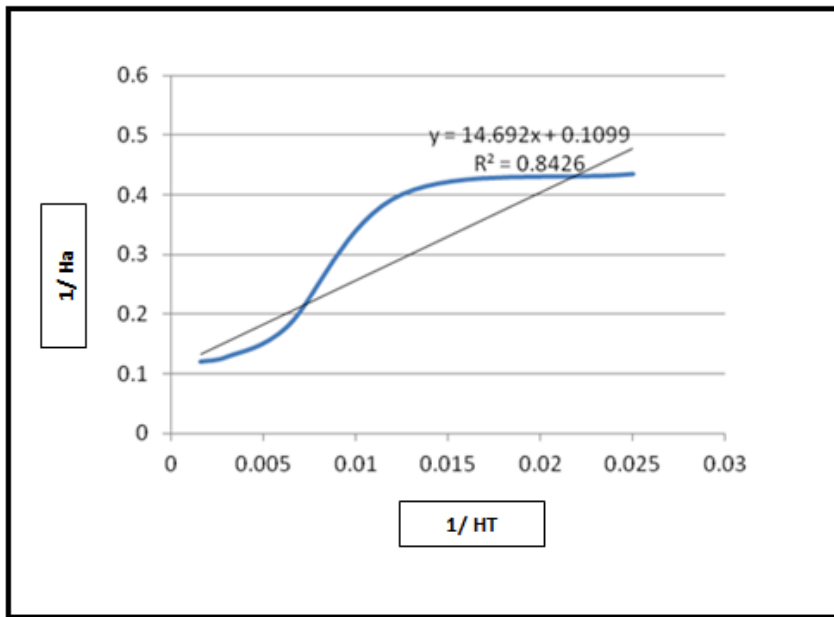
$$Y = \text{constant} + b_1 X$$

$$Y = 14.692 X + 0.1099$$

Linear equation

$R^2 =$ coefficient of determination.

$$R^2 = 0.8426$$



Ha = number of prey consumed; H = initial prey density

Figure 1 . Functional response of *S. sexmaculatus* adult females to *T. urticae* adults

The rate of prey consumption by a predator rises as prey density increases, but eventually levels off at a plateau at which the rate of consumption remains constant regardless of increases in prey density.

Wiedenmann and O'Neil (1991) used Holling's disk equation to estimate the parameters T_h and a . Substituting these estimates and the known values for the other variables in the equation produced a curve that fit the laboratory data well, and they obtained an estimate of 9.1 for the maximum predation rate (K) that could be attacked in daylight. This estimate is much higher than that observed in field studies, where the researchers point out that predators may have limitations in addition to handling time in field situations, and caution that functional responses determined in the laboratory may differ in maximum consumption rates,

and even in the shape of the response curve, from those observed in the field.

We can graph the observed number of two-spotted spider mite attacked by *S. sexmaculatus* as a function of *T. urticae* density, and plot the curve fitted using Holling's disk equation ($T = 8$ daylight hours; parameter estimates were $T_h = 0.88$ h and $a = 0.07$ h⁻¹).

There is a specific amount of handling time (T_h) associated with each prey item eaten or attacked' that is invariant to the density of the prey (H) (Table 2), Consequently, while prey items are easier to find as their density increases, handling time per prey item is the same, and the maximum number of prey items eaten or attacked is determined by the ratio of total available searching time to handling time (T/T_h). In other words, at low prey densities, a smaller proportion of a predator time is spent handling prey, even if the predator attacks every prey item available. As prey density increases and more prey are attacked, the proportion of time spent handling prey increases. This proportion reaches a maximum when all available time is spent handling prey ($T = T_h$); at this point, handling time (T_h), rather than prey availability, limits the number of prey items that a predator can consume (and consequently determines the level of the plateau).

(Table 2): Relationship between density of prey and total time of predation

Prey density	Time of search (Hour) $T. \text{ search} = H a / a.H$	Handling time (Hour) $T. \text{ handling} = H a. T_h$	Total time (Hour)
5	0.92	2.024	2.944
10	0.5	2.2	2.7
20	0.56	4.928	5.488
40	0.385	6.776	7.161
80	0.21	7.304	7.514

H_a = number of prey consumed; H = initial prey density; T_h = handling time (day); a = attack rate.

In this study, the predator thrips *S. sexmaculatus* exhibited type III functional response to different densities of adults of the two-spotted spider mites on bean leaf discs at 25°C. The type III (sigmoid) functional response also has been reported for several predator thrips species such as *S. longicornis* in which the proportion of prey killed increased as prey

density (Heidarian *et al.*, 2012), This is also referred to as a positive density-dependent relationship.

In contrast of our findings, the type III functional response has not been reported in other species of the family Thripidae. The type II response has been reported for *S. longicornis* on on adult stage of *T. urticae* (pakyari *et al.*, 2009), *S. takahashii* Priesner on *T. urticae* (Gotoh *et al.*, 2004; Ding-Xu *et al.*, 2007). and *S. takahashii* on *T. viennensis* Zacher (Li *et al.* , 2007).

The maximum predation rate is limited by an upper asymptote defined by the ratio T/Th (K) (Hassell, 1978), which was 9.1 in a day at 25° C for *S. sexmaculatus*. This result is desirable for the biocontrol of *T. urticae* because the optimum temperature which *T. urticae* is present. similar to our findings, estimates of functional response parameters of predator *S. longicornis* showed that the values of attack rate and handling time were very similar when the fed on eggs and nymphs of *T. urticae*, and the maximum attack rate (T/Th) on eggs and nymphs of *T. urticae* was estimated at 9.98 and 9.72, respectively (Pakyari *et al.*, 2009a).

Some factors suchas temperature, age of predator, host plant and prey stage can vary the value of attack rate and handling time of a predator (Gotoh *et al.*, 2004; Ding-Xu *et al.*, 2007; Pakyari *et al.*, 2009b), Pakyari *et al.* (2009) reported the values of handling time and attack rate for *S. longicornis* at 26° C as 1.6156 h and 0.0694 on adult stage of *T. urticae* on bean leaf disc. The reported value of a is greater and T_h is smaller than those obtained in our study. However, there is substantial difference between experimental conditions such as host plant and prey stage.

At higher prey densities, predators may spend less time on individual prey because prey accidentally bumping into a feeding predator may cause the predator to abandon the prey it is eating and attack another. The bumping of prey into each other may cause prey to move, thereby increasing the chance of an encounter with a predator. This higher prey density results in wasteful killing (Metz *et al.*, 1988) as a predator may partially eat multiple prey instead of eating one whole prey. Predation rate reaches a plateau at higher prey densities due to factors such as satiation (Sabelis, 1985; Sabelis, 1986).

At the density of one prey per leaf, predators survived but hardly laid any eggs. The increase in oviposition in response to the increase in prey

density adds to the effectiveness of biological control by causing an increase in predator population.

Mutual interference denotes the adverse influence of predator density on the instantaneous success of individual predator (Arditi and Akcakaya 1990). However, spatial complexity and aggregation also have roles in predator-prey interactions (Hassell and May 1973; Free *et al.*, 1977). Under field conditions, interference probably leads to the emigration of individual predators from regions of high parasite density (Rogers and Hassell, 1974). Begon *et al.*, (1996) studied mutual interference with an unlimited number of preys. But 40 preys are large for predator as far as their predation rate is concerned. So the effects of mutual interference will not be mixed up with the effects of competition for food. In the present study, predator interference affected the rate of prey consumption. However, the natural dispersal of predators to explore for more preys will reduce this interference behavior among predators in field.

Results reported here form a database for further studies on the feasibility to incorporate *S. sexmaculatus* in integrated pest management programs against *T. urticae*.

References

- Alzoubi, S. and S. Cobanoglu 2008. Toxicity of some pesticides against *Tetranychus urticae* and its predatory mites under laboratory conditions. American Eurasian J. Agricultural and Environmental Sci., 3(1): 30-37.
- Arditi, R., Akcakaya, H.R. 1990. Underestimation of mutual interference of predators. Oecologia 83: 358-361.
- Begon, M., Harper, J. L, Townsend, C. R. 1996. Ecology: Individuals, Populations, Communities, third edition. Blackwell Scientific Publications. Cambridge, MA.
- Coville, P. L. and W. W. Allen 1977. Life table and feeding habits of *Scolothrips sexmaculatus* (Thysanoptera: Thripidae). Annals of the Entomological Society of America, 70: 11-16.
- Ding-Xu, L., Juan, T. and Zuo-Rui, S. 2007. Functional response of the predator *Scolothrips takahashii* to hawthorn spider mite, *Tetranychus viennensis*: effect of age and temperature. BioControl 52: 41-61.
- Dixon, A.F.G. 2000. Insect predator prey dynamics ladybird beetles and biological control. Cambridge University Press, Cambridge, 275pp.
- Duso, C., V. Malagnini, A. Pozzebon, M. Castagnoli, M. Ligouri and S. Simoni 2008. Comparative toxicity of botanical and reduced-risk insecticides to Mediterranean populations of *Tetranychus urticae* and *Phytoseiulus persimilis* (Acari, Tetranychidae, Phytoseiidae). Biological Control., 47: 16-21.
- Enkegaard, A., 1994. Temperature dependent functional response of *Encarsia Formosa* parasitizing the Poinsettia-strain of cotton whitefly, *Bemisia tabaci* on Poinsettia Entomol. Exp. Appl. 73: 19–29.
- Fathipour, Y., Hosseini, A., Talebi, A.A., Moharrampour, S., 2006. Functional response and mutual interference of *Diaeretiella rapae* (Hymenoptera: Aphidiidae) on *Brevicoryne brassicae* (Homoptera: Aphididae). Entomol. Fennica 17, 90 – 97.

- Free, C. A. , Beddington, J. R., Lawton, J. H. 1977. On the inadequacy of simple models of mutual interference for parasitism and predation. *Journal of Animal Ecology* 46: 543-554
- Garcia-Mari, F. and Gonz'alez-Zamora, J. 1999. Biological control of *Tetranychus urticae* (Acari: Tetranychidae) with naturally occurring predators in strawberry plantings in Valencia, Spain. *Experimental and Applied Acarology* 23: 487-495.
- Gilstrap, F. E. and E. R. Oatman 1976. The bionomics of *Scolothrips sexmaculatus* (Pergande) (Thysanoptera: Thripidae), an insect predator of spider mites. *Hilgardia*, 44: 27-59.
- Gitonga, L.M., Overholt, W.A., Lohr, B., Magambo, J.K., Mueke, J.M., 2002. Functional response of *Orius albidipenis* (Hemiptera: Anthocoridae) to *Megalurothrips sjostedti* (Thysanoptera: Thripidae). *Biol. Con trol*. 24, 1 -6.
- Gotoh, T., Nozawa, M. and Yamaguchi, K. 2004. Prey consumption and functional response of three acarophagous species to eggs of two-spotted spider mite in the laboratory. *Applied Entomology and Zoology* 39, 97-105.
- Hassell, M. P., May, R. M. 1973. Stability in insect host-parasite models. *Journal of Animal Ecology*, 42: 693-726
- Hassell, M. P. 1978. Dynamics of arthropod predator-prey systems. Princeton University Press.
- Heidarian, M., Y. Fathipour and K. Kamali. 2012. Functional response, switching, and prey-stage preference of *Scolothrips longicornis* (Thysanoptera:Thripidae) on *Schizotetranychus smirnovi* (Acari: Tetranychidae), *Journal of Asia-Pacific Entomology* 15: 89 - 93.
- Holling, C. S. 1959a. The components of predation as revealed by a study of small mammal predation of European pine saw fly. *Canadian Entomologist* 91: 293-320
- Holling, C. S. 1959b. Some characteristics of simple types of predation and parasitism. *Canadian Entomologist* 91: 385-398

- Holling, C. S. 1963. An experimental component analysis of population process. Memoirs of Entomological Society of Canada 32: 22-32
- Holling, C. S. 1965. The functional response of predators to prey density and its role in mimicry and population regulation. Mem Entomol Soc Can.; 48: 3-60.
- Kishimoto, H., Takagi, K., 2001. Evaluation of predation on *Panonychus citri* (McGregor) (Acari: Tetranychidae) from feeding traces on eggs. Appl. Entomol. Zool. 36, 91 -95.
- Li, D.X., Tian, J., Shen, Z.R., 2007. Effects of pesticides on the functional response of predatory thrips, *Scolothrips takahashii* to *Tetranychus viennensis*. J. Appl. Entomol. 130, 314-322.
- Metz, J. A. J., Sabelis, M. W., Kuchlein, J. H. 1988. Sources of variation in predation rate at high prey densities: an analytic model and a mite example. Experimental and Applied Acarology 5: 187-205
- Modarres, N., Vafaei, R., Zamani, A. A., Arbabi, M. and Farazmand, H. 2011. Effect of nitrogen fertilization on *Tetranychus urticae* Koch. (Acari:Tetranychidae) populations on common bean cultivars. Middle-East Journal Scientific Research, 8(5): 990-998.
- Murdoch, W. W., Oaten, A. 1975. Predation and population stability. Advances in Ecological Research. 9: 2-131.
- Parvin, M. M., M. A. Asgar and M. M. Haque. 2010: Voracity of three predators on two-spotted spider mite, *Tetranychus urticae* (Koch) (Acari: Tetranychidae) and their development stages. Research Journal of Agriculture and Biological Sciences, 6(1): 77-83.
- Pakyari, H. and Fathipour, Y 2009a: Mutual interference of *Scolothrips longicornis* Priesner (Thysanoptera: Thripidae) on *Tetranychus urticae* Koch (Acari: Tetranychidae). IOBC-WPRS Bull. 50: 65-68.
- Pakyari, H., Fathipour, Y., Rezapanah, M. and Kamali, K. 2009b: Temperature-dependent functional response of *Scolothrips longicornis* (Thysanoptera: Thripidae) preying on *Tetranychus urticae*. J. Asia-Pacific Entomol. 12: 23-26.

- Rogers, D. J., Hassell, M. P. 1974. General models for insect parasite and predator searching behavior: Interference. *Journal of Animal Ecology* 43: 239-253
- Sabelis, M. W. 1985. Predation on spider mites. In: Helle W, Sabelis MW, Editors. *Spider mites. Their Biology, Natural Enemy and Control*. pp. 103-127. Elsevier.
- Sabelis, M. 1986. The functional response of predatory mites to the density of two spider mites. pp. 298-321 in Metz, J. and Diekmann, O. (Eds). *The dynamics of physiologically structured populations, lecture notes in biomathematics*. 511 pp. Springer Verlag, Berlin, Germany.
- Sengonca, C. and S. Gerlach. 1983. A new developed method "leaf-island" for observation on thrips in the laboratory . *Turk. Bit. Kor. Dery*, 7: 17-22.
- Van Driesche, R.G., Bellows, T. S., 1996. *Biological Control*. Chapman and Hall, New York. 539 pp.
- Wiedenmann, R. N. and O'Neil. R. J. 1991. Laboratory measurement of the functional response of *Podisus maculiventris* (Say) (Heteroptera: Pentatomidae). *Environmental Entomology*. 20 (2):610-614.

Received	2015/7/7	إيداع البحث
Accepted for Publ.	2016/1/21	قبول البحث للنشر