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PLANT TEXTURE AND PREY DENSITY OF THE TWO SPOTTED SPIDER MITE *Tetranychus urticae* KOCH AFFECTING THE FUNCTIONAL RESPONSE OF THE PREDATORY MITE *Neoseiulus californicus* (McGREGOR) (ACARI: PHYTOSEIDAE)

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ABSTRACT

Effect of plant texture and prey density of the two spotted spider mite *Tetranychus urticae* on the functional response of predatory mite *Neoseiulus californicus* females was investigated using bean, soy bean, cotton, apple and eggplant. Feeding capacity of female *N. californicus* was highly affected by the plant texture and prey density. Results indicated that walking speed and activity of *N. californicus* declined when the predatory mite was reared on much hairy leaves compared with few hairy leaves. Based on Holling's disk equation, the female showed search rate (á) was the highest value of 1.238 occurred at the eggplant, followed by the apple 1.127, bean 1.093 and soy bean 1.064, while the shortest search rate was 1.047 for the cotton. It is obvious that the handling time (T_h) per prey was shortest at bean (0.013 day) than that at all plants of soy bean (0.0144 day), cotton (0.0152 day), apple (0.0302 day) and eggplant (0.0567 day).

Keywords: *Neoseiulus californicus*, *Tetranychus urticae,* Plant texture, Prey density, Functional response.

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 (Zhang, 2003). Spider mite problem increased when natural enemies are destroyed by applications of broad spectrum insecticides, applied against other pests (Mainul Haque *et al.,* 2010). Biological control stands as a profitable alternative to the use of chemicals in the agroecosystem (Lester *et al.,* 2000). 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 its behavioral characteristics including functional response and searching rates (Fathipour *et al.,* 2006). The relationship among the number of prey consumed per predator individual and prey density was defined as functional response (Tully *et al.,* 2005), it plays a critical role in the perspective of prey-predator interactions and their ecological and evolutionary consequences.

The functional response concept first described by Holling (1959), has been widely utilized to evaluate effectiveness of predacious insect and mites (Reis *et al*., 2003; Badii *et al*., 2004 and Timms *et al*., 2008). In general, the functional response of a predator to a prey could follow one of three mathematical models: Type I (linear), Type II (convex) or Type III (sigmoid). In the Type I model, the proportion of prey consumed increases linearly with prey availability up to a maximum. In the Type II model, the proportion of prey consumed declines monotonically with prey density. Type III model depicts a sigmoid relationship in which the proportion of prey consumed is positively density-dependent over some region of prey density (Holling, 1959 and Timms *et al*., 2008). 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 (Fernández-Arhex and Corley, 2003 and 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 (Hughes *et al*., 1992 and Fernández-Arhex and Corley, 2003).

The predaceous mite *Neoseiulus californicus* (McGregor) is one of the major biological control agents of tetranychids in greenhouses of several countries (Marafeli *et al.,* 2011). This species is a widespread Type II phytoseiid mite (Luh and Croft 2001). *N. californicus* can also develop and establish a fair population using pollen as a food source (Castagnoli and Simoni, 1999).

The objective of this study is to assess the effect of plant texture and different prey densities on the functional response of the predatory mite *Neoseiulus californicus* when fed on immature stages of *Tetranychus urticae* to improve our understanding of prey-predator interaction and get a better strategy for the biological control of *T. urticae* using *N. californicus*.

MATERIALS AND METHODS

Maintenance of mite cultures:

Laboratory cultures of the mites were established from field collections of spider mite and phytoseiid made in agricultural crops and weeds. Mite cultures were maintained in separate climatic room at 25 ± 2°C, 60: 70 % RH under a 16: 8 h L: D (Light: Dark). Predatory mites were reared on detached mulberry leaves prepared as follows. Several young, fully expanded mulberry leaves were placed underside up on a wet cotton wool layer in foil-dishes (20X 15 cm. in diameter and 2 cm. deep).The wet cotton wool prevented mite escape and maintain leaf freshness for a week. The cotton wool was moisten by adding water where necessary. Predatory mites were fed on all the developmental stages of *T. urticae*.

Functional response:

The functional response of the phytoseiid mite *N. californicus* on *T. urticae* immature stages was investigated in separate bioassays using a protocol similar to that described by Reis *et al.* (2003). Plant leaf disc (3 cm diameter) from five plants (Bean *Phaseolus vulgaris* L., Soy bean *Glycine max* L., Cotton *Gossypium barbadens* L., Apple *Malus sylvesters* L., and Eggplant *Solanum melongena* L.) was placed on a moistened filter paper and over a thin wet sponge, inside a Petri dish (8.0 cm diameter - 1.5 cm depth). The Petri dish was then sealed with parafilm to prevent mite escape. *T. urticae* immature stages were introduced as prey onto the leaf disc inside the Petri dish at densities of (5, 10, 15, 20, 25, 30 and 35 per arena). *N. californicus* female was starved for 24 hours before tested. Starved predators were transferred to the experimental arena using smooth hair brush and left for 24 hrs. Each density treatment was replicated ten times. The controls consisted of arenas with the same densities of *T. urticae* immature stages but without predacious mite. After 24 hrs, the numbers of killed *T. urticae* immature stages were recorded.

Data Analysis:

The functional response of predator to different plants and prey densities was expressed by fitting the data to Holling's disc equation (Holling, 1959):

$$N_a = áTN/ (1+aT_hN)$$

Where: N_a defines the number of prey attacked by a predator per time unit, á is search rate of a predator, T is the total time of exposure time (1day in this experiment), N is the original number of prey items offered to each predator at the beginning of the 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). Search rate and handling time were calculated from linear regression of disc equation. The relationship between the mean number of consumed prey versus original number of prey offered to predator at the beginning of the experiment (prey consumed) / (prey density x 100) for all plants were estimated.

The numerical data collected were computerized by using SPSS program (Statistical Package of Social Science) program, version 16.0.0, 2007. Significant differences of *N. californicus* by plant texture and prey density were performed by Independent-Samples T test and One-Way ANOVA test ($p < 0.05$).

RESULTS AND DISCUSSION

Predatory capacity potential:

Data obtained in table (1) showed that feeding capacity of female *Neoseiulus californicus* when fed on immature stages of *Tetranychus urticae* was highly affected by the plant texture and prey density.

Comparing effect of plant leaf texture on feeding capacity of predacious mite *N. californicus* among the five plants leaves revealed no significant differences at density five and ten of prey ($F = 1.595$; $P = 0.192$ and $F = 0.677$; $P = 0.612$) respectively, while significant differences at density fifteen of prey ($F = 9.933$; $P < 0.05$), twenty ($F = 35.175$; $P < 0.05$), twenty five ($F = 106.488$; $P < 0.05$), thirty ($F = 116.369$; $P < 0.05$) and thirty five ($F = 89.789$; $P < 0.05$). The present results clearly indicated that walking speed and activity of *N. californicus* declined when the predatory mite was reared on much hairy leaves compared with few hairy leaves. That may be the reason why the feeding capacity of *N. californicus* was lower on hairy leaves such as eggplant while it was at its highest level on smooth or fine hairy leaves such as bean. Similar results were previously obtained by Gillespie and Quiring (1994) who found that life span and reproduction of *Phytoseiulus persimilis* were lower on tomato leaves than on beans and the feeding capacity was higher on beans than on tomato leaves. Feeding capacity and fecundity of the predatory mite *Phytoseiulus persimilis* fed on nymphal stages of the two - spotted spider mites were highly affected by the plant texture and rearing substrates (Nassar *et al.,*2010).

Table (1): Effect of plant leaf texture on predation capacity of female predacious mite *Neoseiulus californicus* when fed on immature stages of *Tetranychus urticae* at 25 ± 2 ^{o}C and 65 ± 5 % RH during 24 hrs.

Density of prey	Mean (±SD) number of *T. urticae* killed				
	Bean	Soy bean	Cotton	Apple	Eggplant
5	4.9 ± 0.31 a	4.8 ± 0.36 ab	4.7 ± 0.67 ab	4.6 ± 0.69 ab	4.2 ± 0.91 b
10	9.7 ± 0.67 a	9.7 ± 0.67 a	9.6 ±0.69 a	9.6 ± 0.69 a	9.2 ± 1.13 a
15	14.5 ± 1.08 a	14.5 ± 0.84 a	14.5 ± 0.97 a	12.7 ± 1.33 b	12.0 ± 1.63 b
20	19.6 ± 0.69 a	19.2 ± 0.78 a	17.0 ± 2.86 b	15.4 ± 1.34 c	12.3 ± 1.25 d
25	21.1 ± 1.37 a	20.6 ± 1.26 ab	19.7 ± 1.41 b	15.3 ± 1.16 c	11.5 ± 1.08 d
30	19.4 ± 1.34 a	19.3 ± 1.15 a	18.9 ± 1.66 a	15.0 ± 1.15 b	9.3 ± 0.94 c
35	18.6 ± 1.57 a	16.9 ± 1.28 b	17.1 ± 1.1 bc	13.4 ± 1.26 d	9.0 ± 1.15 e

Means in a row followed by different letters are significantly different (LSD Test, P < 0.05)

Functional response:

Obtained results in fig. (1) showed increase in the number of consumed prey at decreasing rate of prey density where curve slope consumption decreased gradually until leveling off. These specifications concurred with Type II functional response that predator appear towards varied densities of its prey which is determined by consumption of predator and handling time. Timms *et al.* (2008) reported that many of the predators that have been successfully released as biological control agents have been shown to exhibit the Type II functional response on their prey. *N. californicus* is a widespread Type II phytoseiid mite (Luh and Croft 2001). This species is one of the most effective phytoseiid mites used for spider mite management in many agricultural crops and fruit orchards (Castagnoli *et al.,* 1995). In general, *N. californicus* consumed the highest number of prey (immature stages of *T. urticae*) on bean leaves, while consumed the lowest on eggplant leaves (Fig. 1).

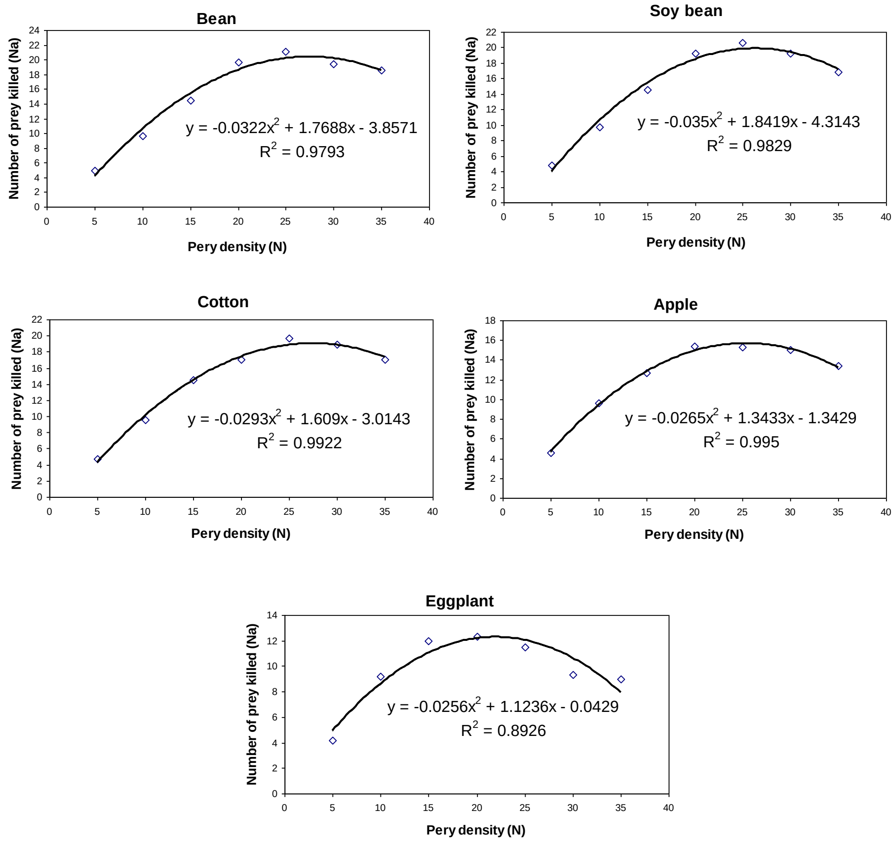

Fig. (1): Relationship between number of *Tetranychus urticae* preyed on by a female of *Neoseiulus californicus* and the density of immature stages of *T. urticae* provided per day. For leaves of all five plants species, the data followed the Type II (convex) functional response model in which the number of prey consumed increased with prey availability but began to decrease when a maximum point was reached.

Comparison of functional response curves revealed that there was no significant difference between the functional response of predator on all leaves of plants except between bean and eggplant. This could be explained as the following, the difference between the functional response of *N. californicus* fed on immature stages of *T. urticae* on leaves of bean and (soy bean, cotton, and apple) was (F = 0.38; df = 11.982; P = 0.849), (F = 181; df = 11, 878; P = 0.678) and (F = 1.822; df = 10. 332; P = 0.202) respectively, also on leaves of soy bean and (cotton, apple and eggplant) was (F = 0.051; df = 11.953; P = 0.825), (F = 1.213; df = 10.564; P = 0.292) and (F = 3.728; df

= 8.602; P = 0.077) respectively, on leaves of cotton and (apple and eggplant) was (F = 0.727; df = 10.928; P = 0.411) and (F = 2.786; df = 8.909; P = 0.121) respectively, finally on leaves of apple and eggplant was (F = 0.811; df = 10.769; P = 0.386). Whereas difference between the functional response curves of predator between bean and eggplant leaves was significant (F = 4.964; df = 8.425; P = 0.046).

The percentage of prey consumed of *N. californicus* was negatively correlated with the offered prey densities (Fig. 2). Obtained results were fitted to second degree of polynomial. Results presented in table (2) showed that the rate of successful search (á) was the highest value of 1.238 occurred at the eggplant, followed by the apple 1.127, bean 1.093 and soy bean 1.064, while the shortest search rate was 1.047 for the cotton.

It is obvious that the handling time (T_h) per prey was shortest at bean (0.013 day) than that at all plants of soy bean (0.0144 day), cotton (0.0152 day), apple (0.0302 day) and eggplant (0.0567 day). Obtained results were fitted to second degree of polynomial with R^2 value of 0.9793, 0.9829, 0.9922, 0.995 and 0.8929 for bean, soy bean, cotton, apple and eggplant respectively (Table 2). Different factors may influence the handling time of natural enemies, e. g. the speed of predator and prey movement and the time spent subduing a prey individual, which again may relate to prey defense mechanisms, both behavioural and structural (Hassell, 1978). Our results were in agree with Madadi *et al*. (2007) who conducted similar study on *Neoseiulus cucumeris* and reported that the presence of trichomes on eggplant mechanically impeded the movement of *N. cucumeris* and/or decreased its reactive distance resulting in increased handling times compared with that on the smooth leaved sweet pepper.

Table (2): Estimates of functional response parameters from linearization of Holling's Type II model.

Plant	á	T_h	T/T_h	R^2
Bean	1.093	0.013	76.92	0.9793
Soybean	1.064	0.0144	69.44	0.9829
Cotton	1.047	0.0152	65.79	0.9922
Apple	1.127	0.0302	33.11	0.995
Eggplant	1.238	0.0567	17.63	0.8929

The results demonstrated that the calculation of the search rate (à) and handling time (T_h) had been associated with the changes of plant texture. It had revealed generally increasing in the search rate and decreasing in handling time related to plants texture on predator when fed on immature stages of the prey. Skirvin and Williams (1999) stated that plant species had a significant effect on movement of the prey *T. urticae*. Phytoseiid mite species live mostly on leaf undersurface that have raised viens, dense hairs, tunneled margins and cave - like structures in the vein axils which called domatia.

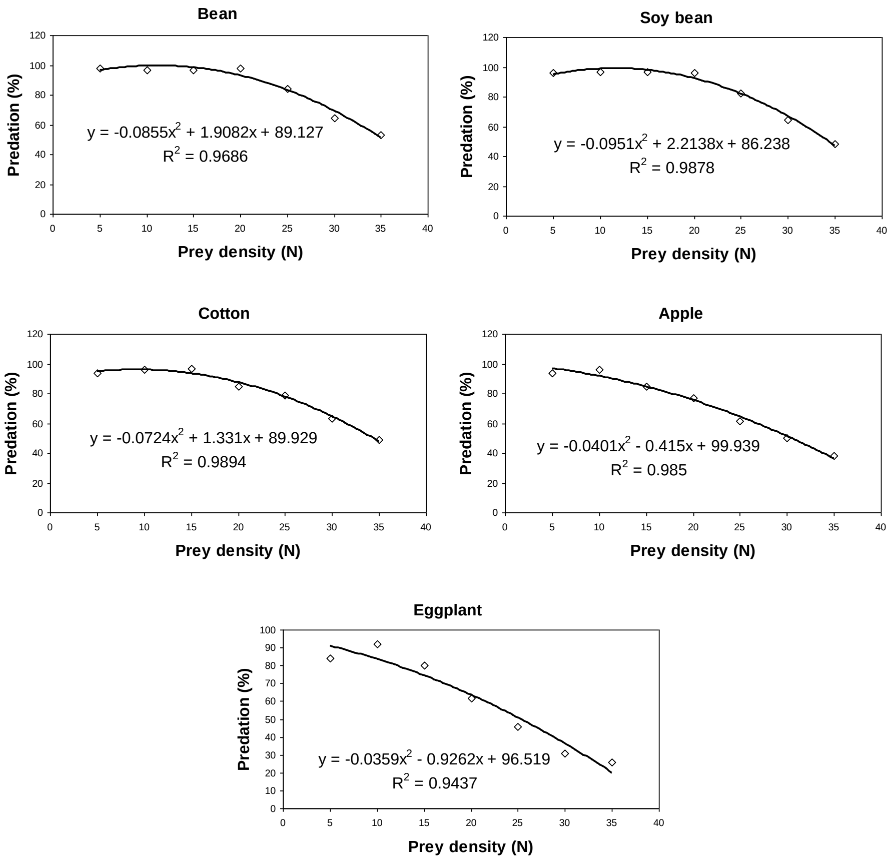

Fig. (2): Percentages of predation of *Neoseiulus californicus* to *Tetranychus urticae* at 25 ± 2 °C and 65 ± 5 % RH.

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تأثير السطح النباتى وكثافة فريسة العنكبوت الأحمر ذو البقعتين *Tetranychus urticae* علـى كفـاءة الإفتـراس للمفتـرس الأكاروسـى *Neoseiulus californicus*

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تـأثير السطح النبـاتى علـى كفـاءة الإفتـراس لإنـاث المفتـرس الأكاروسـى *Neoseiulus californicus* عند التغذيـة علـى كثافـات مختلفـة من الأطـوار غير البالغـة للعنكبـوت الأحمـر ذو البقعتين *Tetranychus urticae* علـى أوراق نباتـات الفاصـوليا وفـول الصـويا والقطـن والتفـاح والباذنجان. أثّر السطح النباتى وكثافة الفريسة إلـى حد كبيرعلـى السعة الغذائيـة للأنثـى ، و أشـارت النتـائج بـأنّ سرعة التنقّل ونشـاط المفتـرس الأكاروسـى *N. californicus* انخفض عندما ربـى المفترس على الأوراق كثيفة التشعير بالمقارنة بالأوراق قليلة التشعير. فى معادلة Holling أظهرت النتائج أن معامل الهجوم (á) للأنثى كان الأعلى على أوراق الباذنجان 1.238 يليها التفاح 1.127 ثم الفاصوليا 1.093 وفول الصويا 1.064، بينما معامل الهجوم الأقل كان على أوراق نبات القطن 1.047. وقت المعالجة (T_h) كان أقصر في الفاصـوليا (0.013 يوم) من بـاقى النباتـات ثم فول الصويا (0.0144 يوم) والقطن (0.0152 يوم) ثم التفاح (0.0302 يـوم) والباذنجـان (0.0567 يوم).

قام بتحكيم البحث

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