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PREY CONSUMPTION AND FECUNDITY OF *Phytoseiulus persimilis* ATHIAS-HENRIOT FED ON DIFFERENT STAGES AND DENSITIES OF *Tetranychus urticae* Koch. (ACARI: PHYTOSEIIDAE: TETRANYCHIDAE) UNDER LABORATORY CONDITIONS

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ABSTRACT: The effect of different prey densities and prey stages of *Tetranychus urticae* on feeding capacity and fecundity of *Phytoseiulus persimilis* adult females was studied on leaf discs of eggplant, *Solanum melongena* L. (Black Baladi cultivar) during ten days under laboratory consistent conditions of 25 ± 2°C and 65 ± 2% R.H.. The following prey densities were tested: 5, 10, 15 and 20 for the tested stages of prey (eggs, larvae, males and females). It was found that all of the prey tested stages were eaten by *P. persimilis* females. The total average of devoured prey individuals per predator female during ten days was significantly ($P \leq 0.05$) affected by stage and density of the introduced prey. In all cases, number of preys consumed by predator was increased with increasing prey density. *P. persimilis* consumed more eggs and larvae than males and females of the prey. Total averages of consumed *T. urticae* eggs and larvae were 35.5, 23.7; 67, 40.1; 82.2, 54.0 and 118.8, 77.2 at prey densities of 5, 10, 15 and 20, respectively. The highest consumption was detected when the predator fed on *T. urticae* stages at a density of 20/prey. Eggs laid by predator female were differed significantly ($P \leq 0.05$) according to stage and density of the introduced preys during the experimental period. The greatest number of deposited eggs was observed when feeding on *T. urticae* eggs followed by females at different prey densities. Total averages of *P. persimilis* eggs were 10.7, 19.4, 29.7 and 32.7 eggs (for prey eggs) as well as 9.2, 13.4, 22.5 and 25.9 eggs (for prey females), at prey densities of 5, 10, 15 and 20, respectively. Differences in total number of deposited eggs of *P. persimilis* were not significant ($P \leq 0.05$) when the predator was provided with larvae, males and females at each of the tested densities of *T. urticae*. A positive and high significant correlation was found between densities of prey stages and each of feeding capacity and fecundity of the predator. Daily number of deposited eggs was gradually increased to reach the highest value on the sixth day in most cases. Thereafter, the deposited eggs were decreased to the end of experiment. The present study suggests the possibility of utilization *P. persimilis* as an ideal biocontrol agent to reduce *T. urticae* populations on eggplants.

Key words: *Phytoseiulus persimilis*, *Tetranychus urticae*, feeding capacity, prey densities, prey stages, fecundity, eggplant.

INTRODUCTION

Eggplant, *Solanum melongena* L., is an important solanaceous vegetable crop grown in the world. It is being grown in almost all the year round. This crop is very important to small and average producers. In 2014, the total areas cultivated with eggplant in Egypt reached 49713 hectares produced approximately 1257913 tons (**FAO, 2014**). Many authors cleared that one of the factors contributing to low yields is injury caused by many arthropod pests, particularly phytophagous mites that are widely spread during the growing season of eggplant (**Adango *et al.*, 2006; Ohno *et al.*, 2012; Azandeme *et al.*, 2015; Abou El-Saad, 2016**). Among the

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latter, the tetranychid mites especially *Tetranychus urticae* Koch is the most economically important species which is considered one of the serious pests in the world (**Wisoki, 1985; Moraes and Flechtmann, 2008; Ozsisli and Cobanoglu, 2011**). *T. urticae* is a polyphagous feeding on more than 600 plant species **(Bolland *et al.* 1998)**, which can increase daily up to 40% (**Krips *et al.*, 1998**).

Acarological studies which were carried out in Egypt revealed that spider mites particularly *T. urticae* may cause remarkable damage to infested different solenaceous crops (**El-Saiedy *et al.*, 2015; Abou El-Saad, 2016; Abou Ouf, 2016; Ali *et al.*, 2017**). Studies have been conducted in different countries to assess the effect and potential of natural enemies for controlling this pest. On the other hand, many of the predaceous phytoseiid mite species are important biological control agents of mite pests in different parts of the world. **Helle and Sabelis (1985) and Hoque *et al.* (2010)** studied the effects of different prey stages of *T. urticae* on *P. persimillis*. The relationship between the numbers of prey consumed per predator and prey density is basic to all predator prey interactions (**Holling, 1959; Hassell, 1978**). Complications in the interpretation of predator responses may arise because functional response can be influenced by a number of factors, including characteristics of predator and prey (**Abrams, 1990**), characteristics of prey and attributes of an environment factors on relationships between prey and predator (**Huffaker *et al.*, 1970**).

Accordingly, the aim of the present work is to determine prey consumption and fecundity of the phytoseiid predatory mite *P. persimilis* when fed on different stages and densities of *T. urticae* under laboratory conditions.

MATERIALS AND METHODS

Experimental Design

This experiment was carried out under laboratory conditions of 25±2ºC, 65±2% relative humidity and 12 hours of photoperiod at the Acarology Laboratory, Faculty of Agriculture, Zagazig University, Egypt. Leaf discs (about 2.5 cm in diameter) of eggplant, *Solanum melongena* L. (Black Baladi cultivar) were used as rearing arenas according to the method described by **Yousef and El-Halawany (1982)**. The leaf discs were placed singly upside down on cotton wool pads socked with water in opened Petri-dishes. Each leaf disc was surrounded by a wet strip of cotton wool to prevent mite individuals from escaping and to supply them with water (**Castagnoli and Simoni, 1999**).

Feeding Capacity and Fecundity of *Phytoseiulus persimilis*

To study the effect of prey stages at different densities on feeding capacity and deposited eggs *P. persimilis*, a total of 40 newly adult mated of females were transferred and placed singly on 40 replicated eggplant leaf discs (as previously described) and provided daily with one of the four densities (5, 10, 15 and 20 preys/leaf disc/ day). Ten replicates were used for each of the tested prey stages (eggs, larvae, males and females of *T. urticae*) .Culture of the predator was fed on different developmental stages of *T. urticae* three times per week. Rearing individuals were examined daily where the devoured prey individuals from each prey stage were recorded and replaced by other alive ones. Also the number of deposited eggs per female was registered daily during ten days.

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using a software package, **CoStat Statistical Software (2005)**, a product of Cohort Software, Monterey, California. Means were compared by calculated least significant differences at $P \leq 0.05$ level of probability. Moreover, the correlation of prey stages and densities of *T. urticae* on feeding capacity and fecundity of *P. persimilis* was detected.

RESULTS AND DISCUSSION

Effect of Different Stages and Densities of *T. urticae* on the Predation of *P. persimilis*

Prey consumption of *P. persimilis* adult females when fed on different stages and densities of *T. urticae* during ten days is shown in Table 1. It was found that *P. persimilis* was able to feed on all stages of the spider mite. The

Table 1 .Prey consumption of *Phytoseiulus persimilis* females fed on different stages and densities of *Tetranychus urticae* during ten days under laboratory conditions

Prey density	Total average of prey stage consumed by *P. persimilis*				$LSD_{0.05}$
	Eggs	Larvae	Males	Females	
5	35.5±3.15	23.7±3.13	16.2±0.89	14.0±0.60	6.917
10	67.8±5.45	40.1±5.19	25.6±0.88	14.6±0.65	11.507
15	82.2±6.15	54.0±5.90	35.0±0.67	16.0±0.60	12.998
20	118.8±7.78	77.2±8.14	45.3±0.69	16.9±0.69	17.099
$LSD_{0.05}$	17.770	17.785	2.400	1.932	

Results are presented as mean ± SE

total average of devoured prey individuals per predatory female during ten days was significantly ($P \leq 0.05$) affected by stage and density of the introduced preys. Prey density also played a significant role in predation of *P. persimilis*. The total average of preys consumed by *P. persimilis* females were obviously increased as the prey density was increased at an accelerated rate when 5 to 20 prey densities were provided. For instances, a total average of eggs consumed by adult female of *P. persimilis* were 35.5, 67.8, 82.2 and 118.8, at 5, 10, 15 and 20 prey individuals, respectively. These results agree with those of **Ashihara *et al.* (1978)**. Moreover, **Souza-Pimentel *et al.* (2018)** reported that *P. macropilis* females consumed all stages of *T. urticae*. As the density of juvenile preys increased, predation also increased (**Hoque *et al.*, 2010**). The same trend was also observed with the same species fed with *T. cinnabarinus* Boisduval (**Friese and Gilstrap, 1982**) or *Panonychus ulmi* Koch (**Jolly, 2000**).

Predator female devoured a considerably greater number of prey individuals when fed on eggs (35.5, 67.8, 82.2 and 118.8 eggs), (23.7, 40.1, 54.0 and 77.2 larvae) than that when fed on males (16.2, 25.6, 35.0 and 45.3 preys) and females (14.0, 14.6, 16.0 and 16.9 preys) at prey densities of 5, 10, 15 and 20 individuals of *T. urticae*, respectively (Table 1). These results are similar with the findings of **Oliveira *et al.* (2007)** who indicated that adult females of the predatory mite *P. macropilis* fed on all stages of the spider mite *T. urticae*, but predation was higher on eggs than on other stages. Moreover, eggs of *T. urticae* was reported as the preferred prey-stage for *P. persimilis* females on rose (**Moghadasi *et al*., 2013). Souza-Pimentel *et al.* (2018)** showed that adults of *P. macropilis* consumed more eggs and larvae of *T. urticae* than other mite developmental stages. The differences in predation capacity on various prey stages may be due to the differences in the ability of spider mites to escape and may also due to the host preference of predatory mite species. Furthermore, the present results showed that *P. persimilis* would prey more on juvenile stages than on adult males or females of *T. urticae* under different prey densities when ample preys were exist. **Hoque *et al.* (2010)** indicated that the food value of different prey stages are important, it appears that the dietetic value of spider mite juvenile seems to be equal to that of eggs.

Daily prey consumption of *P. persimilis* adult female when fed on different stages and densities of *T. urticae* during ten days is illustrated in Fig. 1. As the time elapsed, average number of eaten eggs or larvae by adult mated female of *P. persimilis* was gradually increased to reach the maximum values at fifth or sixth day. Thereafter, these values were progressively declined to the end of experiment (Fig.1 A and B). Ranges of daily *T. urticae* eggs and larvae consumed by *P. persimilis* adult female during ten days were 1.8 to 4.7, 0.8 to 3.9; 3.8 to 9.0, 1.6 to 6.9; 4.9 to 11.0, 2.7 to 8.7 and 8.2 to 16.7, 3.9 to 11.7 at densities of 5,10,15 and 20 preys, respectively. The same trend was observed to certain extent when the predator eaten males and females of *T. urticae* (Fig. 1 C and D). **Ashihara *et al.* (1978)** reported that *P. persimilis* fed on 28.1 spider mite eggs per day. However,

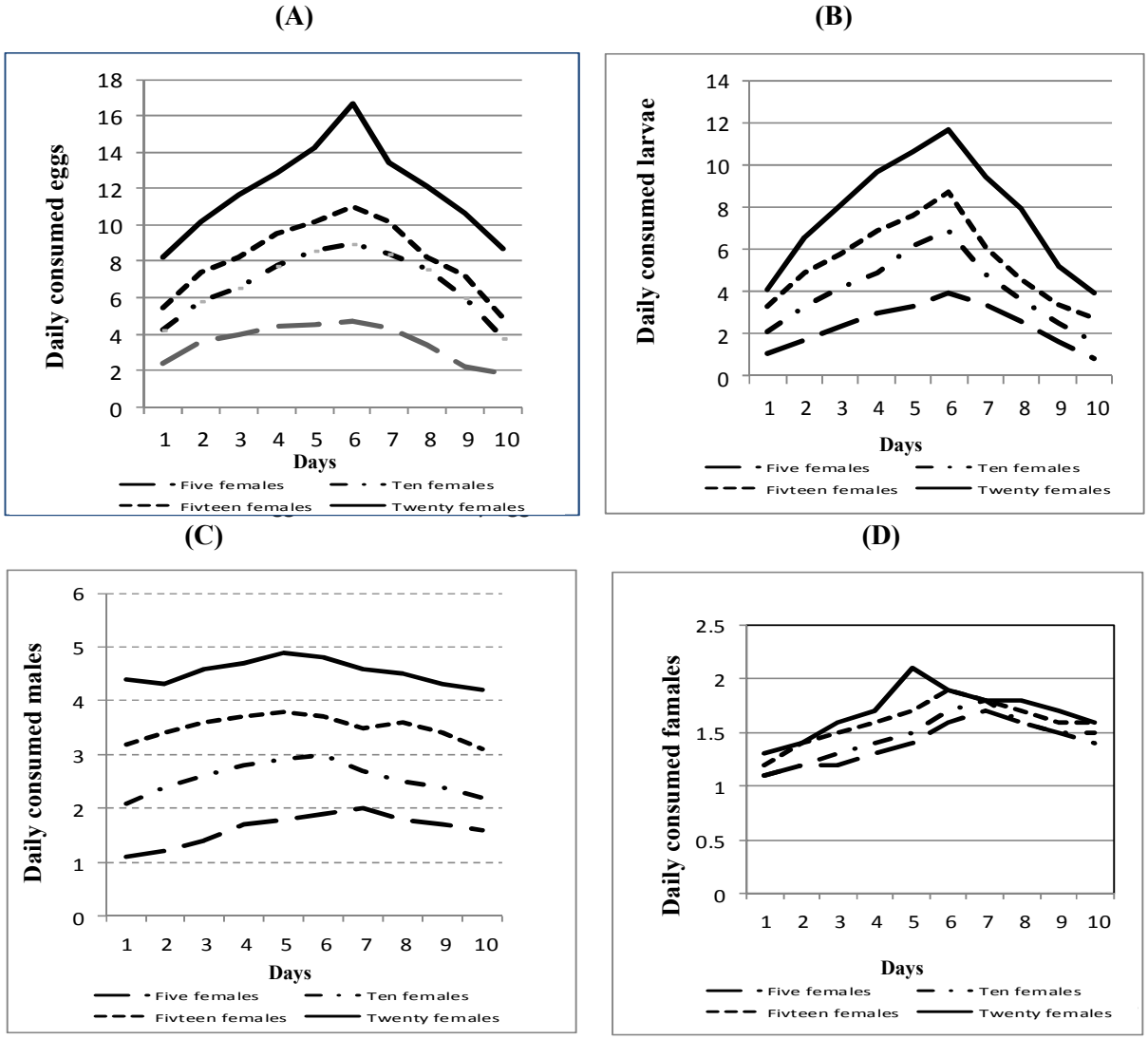

Fig. 1. Daily average number of preys consumed by *P. persimilis* adult females fed on eggs (A), larvae (B), males (C) and females (D) at different densities of *T. urticae* during ten days

Skirvin and Fenlon (2003) showed that predation rate of *P. persimilis* can reach 45 spider mite eggs at 25°C.

Predation among phytoseiid mites may be attributed to variations in structural and chemical characteristics of plants especially trichome and hair density besides mite webs (**Sabelis, 1985; Krips *et al.* 1999; McMurtry *et al.* 2013**). Moreover, environmental factors, *i.e.* temperature and relative humidity may also affect phytoseiid predation. For instance, adult female of *P. persimilis* ate more *T. urticae* eggs as temperature increased from 15 to 25°C, however, the number of consumed eggs was declined at 30°C. (**Skirvin and Fenlon, 2003**).

Effect of Different Stages and Densities of *T. urticae* on Fecundity of *P. persimilis*

The total average of deposited eggs laid by the *P. persimilis* females at various prey stages and densities of *T. urticae* is shown in Table 2. It was clear that, eggs laid by predator female were differed significantly ($P \leq 0.05$) according to stage and density of the introduced prey during the experimental period. The greatest number of deposited eggs was observed when feeding on *T. urticae* eggs followed by females

at different prey densities. Total averages of *P. persimilis* eggs were 10.7, 19.4, 29.7 and 32.7 eggs (for egg prey) as well as 9.2, 13.4, 22.5 and 25.9 eggs (for female prey), at prey densities of 5, 10, 15 and 20, respectively. The parallel values for larvae and males of the prey were 8.4, 8.7; 11.5, 12.1; 19.0, 20.8 and 23.4, 23.9 eggs, respectively. Differences in total number of deposited eggs were not significant ($P \leq 0.05$) when the predator fed with larvae, males and females at each of the tested densities of *T. urticae* (Table 2).

Results in Table 3 show the correlation of prey stages and densities of *T. urticae* on feeding capacity and fecundity of *P. persimilis*. A positive and highly significant correlation was found between number of *T. urticae* offered and number of preys consumed by *P. persimilis*. At the highest density, the predator ate more preys. The opposite was true at the lowest densities. On the other hand, number of deposited eggs by *P. persimilis* female was highly significantly and positively correlated with number of introduced prey.

Daily number of deposited eggs by adult female of *P. persimilis* fed on different stages of *T. urticae* at different densities was gradually increased to reach the highest values at the sixth day in most cases. However, the maximum values of deposited eggs were detected at seventh day when predator female fed 5 and 10 females of *T. urticae*.

The greatest number of deposited eggs was observed when feeding on *T. urticae* eggs followed by females at different prey densities at the highest prey density. These results agree with those obtained by **Oliveira *et al.* (2007)** who showed that the highest oviposition rate of *P. macropilis* was observed when predators fed on eggs and adult females of tetranychid mites. **Escudero and Ferragut (2005) and Abad-Moyano *et al.* (2009)** found that oviposition rate of *P. persimilis* fed on *T. urticae* was 3.9 and 3.7 eggs / female / day, respectively. Moreover, **Souza-Pimental *et al.* (2015)** showed that daily number of eggs laid by a single female of *P. macropilis* fed on *T. urticae* was 2.72 eggs.

On the other hand, the ability of *T. urticae* to develop resistance against new acaricides as well as problems of environmental pollution necessitates scientists to apply biological control as eco-friendly control method. Generally, this study strongly suggests the possibility of utilization *P. persimilis* as an ideal biocontrol agent to reduce populations of spider mites due to its feeding preference, short generation time, high survival rate and ease of its mass production. However, further investigation is needed to determine more information about predator-prey interaction, effect of different biological and ecological factors that may be involved in order to apply this species under protected cultivations which expanded so far greatly in Egypt.

Table 2. Fecundity (No. of deposited eggs) of *P. persimilis* females fed on different stages and densities of *T. urticae* during ten days under laboratory conditions

Prey density	Total average of *P. persimilis* deposited eggs when feeding on different prey stages and densities				$LSD_{0.05}$
	Eggs	Larvae	Males	Females	
5	10.7±0.60	8.4±0.96	8.7±1.03	9.2±0.99	2.77
10	19.4±1.52	11.5±0.81	12.1±1.01	13.4±1.29	3.60
15	29.7±1.82	19.0±1.60	20.8±1.73	22.5±2.11	5.53
20	32.7±1.72	23.4±2.03	23.9±2.12	25.9±2.35	6.26
$LSD_{0.05}$	4.531	4.352	4.697	5.390	

Results are presented as mean ± SE

Table 3. Regression coefficient values between prey stages and densities of *T. urticae* and feeding capacity and fecundity of *P. persimilis* under laboratory conditions.

Prey stage	Prey density/disc	Feeding capacity		Fecundity	
		R^2	Y	R^2	Y
Eggs	5	0.9762**	5.286x+10	0.9601**	1.526x+4.05
Larvae	10	0.988**	3.488x+5.15	0.9771**	1.05x+2.45
Males	15	0.9995**	1.934x+6.35	0.9611**	1.086x+2.8
Females	20	0.9795**	0.202x+12.85	0.9681**	1.184x+2.95

(Y): The value of the equation for the correlation between the prey stages, prey densities and feeding capacity, fecundity of *P. persimilis*.

(R^2): The correlation values at 0.01 level of probability.

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إستهلاك الفرائس والخصوبة لحلم *Phytoseiulus persimilis* Athias-Henriot عند تغذيته على أطوار وكثافات مختلفة لحلم *Tetranychus urticae* Koch (أكارى:فيتوسيدى: تترانكيدى) تحت الظروف المعملية

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تم دراسة تأثير مختلف الأطوار والكثافات المختلفة للحلم العنكبوتي *T. urticae* على القدرة الإفتراسية ووضع البيض لأنثى المفترس *P. persimilis* على أوراق الباذنجان (صنف أسود بلدي) خلال عشرة أيام تحت ظروف المعمل ٢٥ ±٢°م ورطوبة نسبية ٦٥±٢%، كانت الكثافات المقدمة هي ٥ ، ١٠ ، ١٥ و٢٠ من أطوار الفريسة المختبرة (البيض، اليرقات، الذكور والإناث)، أظهرت النتائج أن أنثى المفترس *P. persimilis* قامت بافتراس جميع الأطوار المقدمة من فرائس (البيض- اليرقات- الذكور والإناث)، كما تأثر العدد الكلي للفرائس المستهلكة للأنثى المفترسة خلال ١٠ أيام بوضوح باختلاف كثافة وطور الفريسة المقدمة، ازدادت أعداد الفرائس في كل الحالات بزيادة الكثافة، فضلت أنثى المفترس *P. persimilis* طوري البيض واليرقات أكثر من طوري الذكور والإناث للفريسة، وكان عدد الفرائس الكلي من أطوار البيض واليرقات ٣٥,٥ (٢٣,٧)، ٦٧ (٤٠,١)، ٨٢,٢ (٥٤,٠) و ١١٨,٨ (٧٧,٢) عند الكثافات ٥، ١٠،١٥ و٢٠ من الفريسة علي الترتيب، ظهر معدل الاستهلاك الأعلى عند تغذية المفترس على أطوار الحلم العنكبوتي *T. urticae* عند الكثافة ٢٠، بخصوص البيض الموضوع للمفترس وجد أن كمية البيض الموضوع تختلف اختلافا معنويا باختلاف طور وكثافة الفريسة طوال فترة التجربة، لوحظ أن أعلى معدل لوضع البيض ظهر عند تغذية المفترس على طور البيضة للحلم العنكبوتي *T. urticae* يليه طور الإناث من الفريسة وذلك عند الكثافات المختبرة للفريسة، وكان المعدل الكلي للبيض الموضوع ١٠,٧، ١٩,٤، ٢٩,٧ و٣٢,٧ بيضة (عند التغذية على طور البيضة) و ٩,٢، ١٣,٤، ٢٢,٥ و٢٥,٩ بيضة (عند التغذية على طور الإناث) عند الكثافات ٥، ١٠، ١٥ و ٢٠ على الترتيب، وكانت الاختلافات بين الأعداد الكلية للبيض الموضوع غير معنوية عند تغذية المفترس على أطوار اليرقة والذكور والإناث في الكثافات المختلفة للفريسة، وجد علاقة ارتباط ايجابية عالية المعنوية بين معدل كثافة طور الفريسة وكل من الكفاءة الإفتراسية وخصوبة المفترس وازداد التعداد اليومي للبيض الموضوع تدريجيا ليصل إلى أعلى قيمة في اليوم السادس في معظم الحالات، ويقل بعد ذلك التعداد بالتدريج حتى نهاية التجربة، وبشكل عام تؤيد نتائج هذه الدراسة إمكانية استخدام المفترس *P. persimilis* كعامل مثالي في المكافحة البيولوجية لتقليل تعدادات الحلم *T. urticae* على الباذنجان.

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