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Integration of Certain Acaricides with *Phytoseiulus persimilis* to Control *Tetranychus urticae* on Beans Plants, and Their Sub-Lethal Effect on Its Life-Table Parameters

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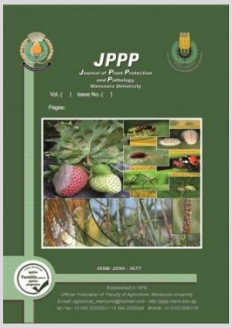

ABSTRACT

The climbed beans(*Phaseolus vulgaris* L.) is one of the export vegetables crops with an economic importance. Beans grown in greenhouses highly infested by the two-spotted spider mite, *Tetranychus urticae* Koch(Acari: Tetranychidae)(TSSM).The present study is to evaluate the field efficacy of three acaricides with or without the predatory mite, *Phytoseiulus persimilis* Athias-Henriot against *T. urticae* on climbed beans under greenhouse condition with a reference to the characteristics of growth and productivity. The field study revealed that the acaricides; agnar 20% SC, penny 9% SC and biomectin 5% EC combined with the predatory mite *P. persimilis* were more effective in controlling TSSM than acaricides or predator mite separately.The acaricide penny or biomectin with *P. persimilis* as a co-treatment significantly increased vegetative growth and productivity. In addition, the sublethal (LC_{25}) effects of these acaricides on *T. urticae* females' life-table parameters were studied in the laboratory. All tested acaricides had a significant effect on *T. urticae* biological parameters such as longevity, total life span, and fecundity. Treatment with agnar, penny and biomectin at LC_{25},significantly reduced the net reproduction(R_0)and gross reproduction (*GRR*)rates of TSSM females. Consequently, the intrinsic rate of increase (r_m) and finite rate of increase(λ)were also affected. In the treated groups and control, the intrinsic rate of increase was 0.129, 0.113, 0.107, and 0.199 female offspring per female per day, respectively. The results showed that the field efficacy of acaricides, as well as sub-lethal effects on TSSM biological characteristics, allow us to obtain a clear image of population level responses to acaricides utilized.

Keywords: Acaricides, Beans productivity, *Tetranychus urticae*, Life table parameters, *Phytoseiulus persimilis*

INTRODUCTION

In Egypt, climbed beans (*Phaseolus vulgaris* L.) is an important export vegetable crop and is highly affected by the infestation of the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) (TSSM). This is considered one of the main economic pests especially on vegetable corps in greenhouses. The greenhouses are ideal for the development of spider mite populations, which can complete a generation in a week under ideal conditions. Furthermore, great fecundity of *T. urticae*, arrhenotokous parthenogenesis, and amazing capacity to adapt to varied hosts and environmental conditions, as well as its rapid developmental rate, enabling it to reach devastating population levels extremely quickly (Sato *et al.,* 2007; Clotuche *et al.,* 2011; Agut *et al.*, 2018).

Spider mite, *T. urticae* has caused significant economic yield losses in many economic crops such as tomato, pepper, cucumber and bean grown in greenhouse (Park and Lee 2005; Abdel-Wali *et al.,* 2012; Tehri *et al.,* 2014). However, its cultivation of these crops is threatened by a number of pests, of which the two-spotted spider mite, which has achieved the major pest status (Haque *et al.,* 2011; Dutta *et al.,* 2012).

In most vegetable and fruit crops, synthetic pesticides are still widely used to control TSSM. This has led to the emergence of resistance to a variety of commonly used acaricides (De Ponti, 1985; Van Pottelberge *et al.,* 2008). Also, many resistance mutations have been recorded associated with target site of pesticides (Khajehali *et al.,* 2010; Ilias *et al.,* 2014). Consequently, the widespread use of pesticides has resulted in *T. urticae* outbreaks in recent decades (Fraulo *et al.,* 2008). Therefore, chemical pesticides must be used with caution due to the environmental and health risks they pose (Horikoshi *et al.,* 2017). Given the economic importance of exporting vegetable crops, it is critical to look for effective alternatives to *T. urticae* control. In this regard, biological control is one of the most cost-effective and environmentally friendly pest control methods available to farmers (Cock *et al.,* 2010).

In some agricultural systems, natural enemies can reduce *T. urticae* populations to levels that cause no economic harm (Nyrop *et al.,* 1998). Phytoseiid mites are the most important biological control agents for spider mites among many natural enemies (McMurtry and Croft, 1997). Phytoseiid mites have been shown to be effective in the management of *T. urticae* on a variety of crops in greenhouses and open fields in several investigations

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(Heikal and Fawzy, 2003; Sarwar *et al.,* 2011, Afifi *et al.,* 2013; Afifi *et al.,* 2015).

To minimize the effect of synthetic pesticides on natural enemies and provide an ecological balance between pests and their enemies, these control strategies can be combined to provide a more reasonable form of pest management (Kogan, 1998). It's important, in the integrated pest management programs (IPM), to select efficient pesticides with little negative effects on the natural enemies or use of pesticide- resistant predatory mites. (Colomer *et al.*, 2011). Thereupon, several studies assessed the impacts of acaricides on both *T. urticae* as a prey and its predators. The sublethal effects can be very subtle and affect populations at concentrations lower than the conventional concentration and may supplement our information about its sublethal effects on physiology and behavior of arthropods (Stark and Banks, 2003; Desneux *et al.,* 2007).

Pesticides' effects on tetranychid mites life-history traits and life-table parameters have previously been investigated (Marcic, 2007; Marcic *et al.*, 2010; Li *et al.,* 2017; Saber *et al.,* 2018). The predatory mite, *P. persimilis* is the main obligatory predator of *T. urticae* (Helle and Sabelis, 1985). To maximize its role as a biocontrol agent, the impact of pesticides on its biology were previously studied by Hassan (1982); Kaplan *et al.,* 2012; Glinushkin *et al.,* 2019; Abdel-Rahman and Ahmed, 2018; Ahmed *et al.,* 2021). Acaricides may impact on TSSM life-history features such as longevity, fecundity, fertility, developmental time, as well as population growth rates of mites that survive pesticide treatment (Stark and Banks, 2003). Bioassays, which address all potential pesticide impacts, provide critical information for IPM strategies (Beers and Schmidt, 2014). It is suggested that life-table analysis is the best method for determining an acaricide's lethal and sublethal effects (Li *et al.,* 2017 and Abdel-Rahman, 2019).

The aim of this study was to evaluate the efficiency of three common and registered acaricides with or without *P. persimilis* on *T. urticae* in bean plants under greenhouse. Also, the effect of sublethal concentration on biological parameters of *T. urticae* under laboratory conditions was studied to provide the information needed in IPM programs via know the impact on the established population growth rate.

MATERIALS AND METHODS

Spider Mite, Cultures

The stock culture of *T. urticae* were collected from leaves of bean plants *Phaseolus vulgaris* L. growing in the farm of Faculty of Agriculture, Cairo University, Egypt. It was reared on leaves of copperleaf shrubs (*Acalypha wilkesiana* Müll. Arg.) in an incubator at 28±2°C, 65±5 % relative humidity (RH%) and (L14:D10 h photoperiod) to maintain a continuous source of them during the experiment.

Predatory Mite, *Phytoseiulus persimilis*

The predatory mite, *P. persimilis* was obtained from leaves of green bean plants, *Phaseolus vulgaris* L. growing in the Unit of Predatory Mites Production in Al Mansouria, Giza Governorate, Egypt.

Tested Acaricides

Agnar 20% SC (Abamectin %2 & Spirodiclofen 18%), penny 9% SC (Emamectin benzoate 1.5% & Indoxacarb 7.5%) and biomectin 5% EC (Abamectin 5%) as an acaricides were used at the recommended rate of 40, 37.5 and 20 ml/100L, respectively. These acaricides were chosen because they are widely used in Egypt and other countries to control TSSM. All selected acaricides belong to different classes of chemicals with different modes of action on mite.

The influence of acaricides together with *P. persimilis* on *T. urticae* (TSSM) under greenhouse condition

The experiment was conducted to assess the influence of the three prementioned acaricides *P. persimilis* against *T. urticae* infesting bean plants (cv. Elhama) growing under greenhouse condition (9×40 m) for the two successive seasons 2018/2019 and 2019/2020. The bean plants received all normal agricultural practices without any pesticide's applications.

The experimental area was divided into three blocks according to the Randomized Complete Block Design. Each block included seven treatments and untreated control. The tested acaricides and the predatory mite were applied singly and combined on the bean plants (treatments), while the control was sprayed with water using a compressor sprayer (20 L capacity).

The two-spotted spider mite, *T. urticae* infestation appeared on bean plants in mid-January, the three acaricides were sprayed at the recommended rates, while *P. persimilis* was released (a single treatment). The predator-prey ratio was 1:10 according to the results of Heikal and Fawzy (2003). Whereas, in the case of acaricide and predator combination as treatments, acaricides were sprayed first, then after two weeks, the predator was released.

The additional acaricides spraying were conducted in 3rd and 6th weeks after the first application and an additional release was conducted during the 3rd week after the first one because of the increase of *T. urticae* population in the single treatments only. Samples of 30 leaves were randomly collected from each treatment, just before releasing predatory mite or spraying acaricides and then weekly afterwards. Samples were carefully examined where numbers of *T. urticae* moving stages/ leaf were recorded. The same technique was repeated in the second season 2019/2020.

The reduction percentage of *T. urticae* movable stages / leaf in bean plants was calculated according to Henderson and Tilton equation (1955)

The influence of tested acaricides on *Tetranychus urticae* life-table parameters

Preparation of LC_{25} of tested acaricides

Under laboratory conditions, leaf discs (2 cm diameter) of fresh leaves of bean plants were dipped in each of the specified acaricide concentrations for one minute and allowed to air dry for one hour. In a Petri dish, five discs from bean leaves were placed on a moist cotton pad (12 cm diameter). Ten adult freshly emerged females of *T. urticae* were transferred to each disc as a replicate (50 adult females for each concentration). After a 24-hour from exposure, the number of dead and survived females was counted. Each bioassay had five concentrations. The bioassays were carried out five times. Control leaf discs were only dipped in distilled water for the same amount of time.

The dishes were maintained at suitable moisture and kept in an incubator at 28±2°C and 60±5% R.H. The bioassay concentrations were chosen based on the recommended concentrations. The concentrations were 80, 40, 20, 10, and 5 ppm, 33.75, 16.875, 8.438, 4.219 and 2.109 ppm and 10, 5, 2.5, 1.25 and 0.625 ppm of agnar, penny and biomectin, respectively.

The lethal (LC_{50}) and sublethal (LC_{25}) values for *T. urticae* adult mite females, treated with tested acaricides, were estimated by Probit-MSChart Program (Chi, 2019) devoted to calculating the probit analyses according to Finney (1971) using mortality data which was corrected by Abbott's formula (1925).

Under laboratory conditions, the effect of LC_{25} concentration of the selected acaricides (agnar, penny, and biomectin) on life table parameters of offspring from *T. urticae* females was evaluated. The experimental methodologies and acaricides were the same as those described previously in preparation of LC_{25} of tested acaricides. Sixty pairs of unmated females together with male individuals of *T. urticae* (< 1 day old) from the laboratory culture were placed on each leaf arena treated by LC_{25} concentration of agnar, penny and biomectin that were 4.79, 3.03 and 0.47 ppm, respectively. In the control, distilled water was used. The surviving pairs of mites from each treatment were transferred to a new clean disc from bean leaf untreated with acaricides as a stock colony after 48 hours of exposure. From stock colony of each treatment, one mated female/replicate was transferred on bean leaf disc (2 cm diameter) placed on wet cotton pads in a Petri dish (6 cm in diameter) and left for 24 h. for ovipositing. All dishes were maintained in an incubator at 28 ± 2 °C, 65 ± 5 % R.H and L14: D10 h photoperiod.

After oviposition, females and all eggs except one were removed from dishes. Thirty eggs as replications /pesticide and the control (n = 120 eggs) were used. The eggs present in each treatment were observed daily until the larvae had emerged. The duration of each developmental stage was tracked until all larvae reached adulthood. During the experiment, disc leaves were replaced every 5 days to keep the leaves as fresh as possible. To examine pre-oviposition and oviposition durations, fertility, and adult longevity, adults were segregated by sex, paired into couples, and transferred to new discs. In discs where males died before females, new males from the stock colony were added to the relevant experimental units. Every day until the completion of the experiment, dead mites and eggs deposited by female individuals in each disc were counted and removed. As proposed by Chi, (1988), life tables were created using data from all individuals tested including females, males, and individuals that died during the development of the immature stage.

Evaluation of growth and productivity characteristics in beans

The influence of tested acaricides as a single treatment or combined with *P. persimilis* against *T. urticae* infesting bean plants on vegetative growth parameters, total yield and its components and pod quality of climbed beans were evaluated.

Growth characters

A representative sample of five plants from each experimental plot was randomly chosen after 65 days from sowing (flowering stage) for measuring plant growth characters: plant height from the soil surface to the highest point of the plant (cm), number of leaves per plant, total chlorophyll reading in leaves was measured as SPAD units using monitor chlorophyll meter (SPAD- 501).

Bean yield and its components

At harvesting time during 75 days from sowing, snap beans were picked weekly through the harvesting period for estimation of yield parameters: Pod weight/plant (g), Number of pods/plant, Total yield/plot (g) (determined for all pickings and calculated as total fresh weight of pods).

Pod quality characteristics

A random sample of 30 pods from each replicate was taken at harvest and examined for the following characters: Total soluble solids percentage according digital refract meter, ascorbic acid content (mg/100g pod fresh weight) in green pod of snap beans, titration methods were used, in which 10 g of green pea seeds were homogenized with 90 mL of oxalic acid (6%) for 10 mins. After that, 2,6 – dichlorophenol indophenol was used to titrate 25 mL of filtrated solution. The results were expressed as mg·100−1 g (FW), as described by El-Mogy *et al.* (2019). Total chlorophyll content (mg/100g pod fresh weight) in pods: it was determined according to AOAC (1990), Total carbohydrates in dry matter of pods according to Dubois *et al.* (1956).

Statistical analysis

Obtained data were subjected to one-way ANOVA "P<0.05" after checking for normality. Means were compared by Tukey's test, admitting significant differences at P<0.05. SPSS software was used for mean comparisons.

Using the TWOSEX MSChart application, the raw data of life table parameters were evaluated according to the theory of age-stage, two-sex life table (Chi, 2020). According to Chi and Su, (2006), the population growth parameters such as (R_0), (r_m), (λ), (T) and (GRR) as well as (s_{xj}), (l_x), (m_x), (f_{xj}) and (v_{xj}) were calculated.

The population parameter means and standard errors were estimated using the Bootstrap procedure with 100,000 re-sampling, and the life table parameters of TSSM untreated (control) and the treated by tested pesticides were compared using a paired bootstrap test (Wei *et al.*, 2020).

RESULTS AND DISCUSSION

Combined effect of acaricides and *Phytoseiulus persimilis* in controlling TSSM

Mean number of *T. urticae* movable stages (TSSM) on leaves of bean plants were generally influenced variably during 2018/2019 and 2019/2020 seasons when compared to the control. Data of single treatment of *P. persimilis* as a predator and three acaricides; agnar 20% SC, penny 9% SC and biomectin 5% EC as recommend acaricides for *T. urticae* as well as *P. persimilis* combined with one of the three acaricides (*P. persimilis* + agnar 20% SC), (*P. persimilis* + penny 9% SC) and (*P. persimilis* + biomectin 5% EC) are listed in Table (1).

Table 1. Effects of three acaricides with or without *Phytoseiulus persimilis* on the mean number of *Tetranychus urticae* movable stages / leaf in climbed bean plants during 2018/2019 and 2019/2020 seasons.

Weekly Sampling	*P. persimilis*	Agnar	Penny	Biomectin	Agnar + *P. persimilis*	Penny + *P. persimilis*	Biomectin+ *P. persimilis*	Control	F	*P*
Mean number of *T. urticae* movable stages /leaflet in bean plants during 2018/2019										
Pre-treatment*	4.73±0.7a	4.68±0.6a	3.90±0.5a	4.60±0.8a	4.45±0.7a	4.05±0.4a	4.43±0.6a	4.98±0.9a	0.226	0.975
1st week	4.55±0.4b	3.05±0.6b	2.65±0.5b	2.95±0.4b	2.35±0.2b	2.55±0.5b	2.13±0.3b	8.40±1.2a	14.35	
2nd week	4.38±0.7b	4.08±0.5b	3.85±0.4b	3.88±0.6b	3.70±0.4b	3.50±0.4b	3.15±0.3b	11.23±0.9a	15.7	
3rd week*	4.50±0.6b	5.20±0.8b	4.95±0.3b	3.95±0.4b	4.75±0.6b	4.38±0.3b	4.48±0.6b	18.45±1.4a	37.45	
4th week	3.68±0.3b	3.33±0.2b	2.73±0.3b	2.48±0.3b	3.13±0.4b	2.80±0.2b	2.58±0.3b	27.38±1.6a	103.5	
5st week	2.53±0.4b	4.88±0.5b	4.13±0.4b	3.50±0.2b	2.75±0.2b	2.20±0.3b	2.00±0.2b	32.10±2.4a	127.1	0.00
6th week**	1.80±0.4b	6.45±0.6b	5.88±0.8b	5.70±0.5b	1.83±0.2b	1.55±0.3b	1.43±0.2b	35.68±3.0a	94.70	
7th week	1.03±0.2bc	5.63±0.5b	4.80±0.3bc	4.50±0.2bc	1.23±0.1bc	0.85±0.2bc	0.68±0.1c	33.83±2.5a	118.5	
8th week	0.40±0.2b	4.13±0.4b	3.88±0.3b	3.13±0.4b	0.78±0.1b	0.60±0.2b	0.43±0.2b	29.28±2.1a	150.3	
9th week	0.30±0.1b	3.30±0.3b	2.98±0.2b	2.88±0.2b	0.30±0.1b	0.13±0.1b	0.10±0.1b	24.30±2.3a	86.19	
Accumulated average	2.57±0.3c	4.45±0.4a	3.98±0.4a	3.66±0.3ab	2.31±0.4cd	2.06±0.3cd	1.88±0.2d		5.195	0.00
Mean number of *T. urticae* movable stages /leaflet in bean plants during 2019/2020									F	*P*
Pre-treatment*	3.20±0.5b	3.70±0.4b	3.10±0.3b	3.63±0.6b	3.43±0.5b	3.45±0.3b	3.05±0.3b	3.15±0.4a	0.16	0.991
1st week	3.15±0.4b	2.30±0.2b	1.90±0.4b	2.20±0.4b	2.18±0.4b	1.88±0.1b	1.63±0.2b	5.18±0.4a	9.53	
2nd week	3.88±0.5b	3.60±0.2b	3.35±0.6b	3.38±0.5b	3.35±0.2b	2.80±0.3b	2.63±0.4b	9.30±0.9a	17.89	
3rd week*	4.38±0.4b	4.70±0.5b	3.65±0.3b	3.70±0.4b	4.18±0.5b	3.68±0.5b	3.40±0.3b	14.23±1.3a	21.53	
4th week	2.93±0.4b	2.83±0.7b	2.23±0.6b	2.15±0.2b	2.60±0.4b	2.58±0.2b	2.33±0.4b	20.88±1.8a	65.96	
5st week	2.80±0.3b	5.75±0.5b	5.13±0.6b	5.50±0.6b	2.43±0.3b	2.08±0.2b	1.90±0.1b	29.35±2.6a	111.9	0.00
6th week**	1.43±0.2c	7.75±0.4b	7.38±0.5b	6.63±0.3b	1.45±0.1c	1.20±0.1c	0.93±0.1c	34.68±2.7a	107.8	
7th week	0.78±0.1b	4.38±0.3b	3.78±0.4b	3.50±0.4b	0.98±0.1b	0.43±0.2b	0.45±0.2b	34.43±2.4a	155.8	
8th week	0.40±0.1b	3.38±0.4b	3.13±0.3b	2.75±0.3b	0.53±0.1b	0.35±0.1b	0.20±0.1b	25.50±2.8a	150.5	
9th week	0.08±0.0b	2.30±0.3b	2.23±0.3b	2.13±0.2b	0.08±0.0b	0.08±0.0b	0.03±00b	20.93±1.9a	118.1	
Accumulated average	2.20±0.2c	4.11±0.3a	3.64±0.5a	3.55±0.3ab	1.97±0.2cd	1.67±0.1cd	1.50±0.2d		4.560	0.01

Means within a row followed by the same letter are not significantly different (Tukey's test: *P* < 0.05).
*** Spraying or releasing ** releasing the predator mite only**

By comparing the single treatments with each other, the present results indicate that the mean number of *T. urticae* movable stages on bean plants significantly highly decreased with the predatory mite treatment compared with the tested acaricides. The accumulated average of *T. urticae* movable stages was 2.57 individual/ bean leaf with the predatory mite, while it was 4.45, 3.98 and 3.66 individual/ bean leaf when mites treated with acaricides agnar 20% SC, penny 9% SC and biomectin 5% EC, respectively during 2018/2019 season.

There were no significant differences observed in numbers of *T. urticae* movable stages when comparing the combine treatments with each other, (*P. persimilis* + agnar 20% SC), (*P. persimilis* + penny 9% SC) and (*P. persimilis* + biomectin 5% EC). The second season 2019/2020 clearly showed a similar trend as the former season. Also, using a combination between the predatory mite with acaricides gave a higher effect than using acaricides alone.

The highest reduction percentages of *T. urticae* movable stages were also recorded when combining the predatory mite (*P. persimilis*) with one of the tested acaricides. The population reduction in mite individuals was 71.29 & 71.78 % and 65.34& 70.58%, during the two successive seasons, respectively (Fig. 1).

The results referred to the combined treatments had the highest effect on *T. urticae* population, followed by the predatory mite treatments which were moderately affected the spider mite population. On the other hand, the tested acaricides had the lowest effect on *T. urticae* compared to the other treatments. These outcomes are consistent with those reported by Afifi *et al.* (2015) who stated that the combination of Milbeknock 1% EC or Nimbecidine 0.03% EC with *P. persimilis* release was highly effective against TSSM on tomato plants in open field. Also, the same results obtained by Alzoubi and Çobanoglu (2010) they stated that the pesticides, hexythiazox, bifenthrin and dimethoate, which were combined with the predatory mites *P. persimilis* and *Neoseiulus californicus* (McGregor) were more effective in controlling TSSM than pesticides or predatory mites alone. Also, El-Saiedy and Fahim (2021) stated that releasing *N. californicus* and applying abamectin 3.6 % EC could be a promising strategy for controlling TSSM on strawberries. Likewise, Richard and Campbell (1999) reported that the integrated control of *T. urticae* using clofentezine in conjunction with the predatory mite *P. persimilis* was more effective than an approach based on chemical or biological measures alone. Moreover, Trumble and Morse (1993) stated that the acaricide abamectin in combination with *P. persimilis* produced the best economic returns.

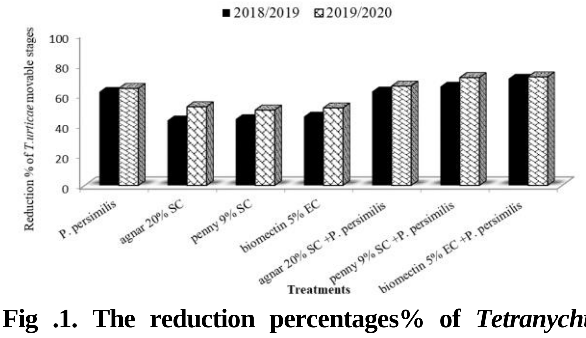

Fig .1. The reduction percentages% of *Tetranychus urticae* on climbed bean plants after treated with three acaricides with or without *Phytoseiulus persimilis* during 2018/2019 and 2019/2020 seasons.

To increase the likelihood of successful TSSM control, a combination of pesticides and predatory mites should be used in a spider mite management strategy, i.e., first reduce the TSSM population by chemical application, followed by predatory mite application on low density

TSSM populations to provide effective control. Several studies have indicated that, despite the effectiveness of phytoseiid predators for biological control of spider mite species, the predators alone may not be able to maintain spider mite populations below the economic injury level for an extended period of time (Field and Hoy, 1986). IPM strategies combine the use of specific pesticides with bioagents (Sterk *et al.,* 2002). As a result, TSSM control can be achieved successfully by combining biological and chemical measures such as short-term residual activity and selective acaricides in conjunction with predators that are more tolerant of the chemical.

The selected acaricides, agnar 20% SC, penny 9% SC and biomectin 5% EC should not be used after the release of *P. persimilis* in IPM programs due to their unfavorable effects on its population parameters according to Ahmed *et al.* (2021). Therefore, the acaricides should be used carefully so that they are sprayed one or two weeks before the release of the predatory mite to get rid of the remaining effect, and use acaricides with short residual activity, selective acaricides and predators that are more tolerant to pesticides.

Influence of tested acaricides on *Tetranychus urticae* life-table parameters

The sublethal concentration LC_{25} effects of the three acaricides (agnar 20% SC, penny 9% SC and biomectin 5% EC) were evaluated on developmental stages and life table parameters of *T. urticae* are listed in Tables (2, and 3). The egg incubation and larva developmental time of both female and male was not significantly affected by LC_{25} of the tested acaricides. While the developmental times of nymphs were significantly affected by penny for both female and male.

The longevity of female and male adult female offspring from females exposed to LC_{25} values of the previous mentioned tested acaricides were shorter in comparison with control. Furthermore, a sublethal effect study clearly demonstrated that when exposed to LC_{25} of agnar, penny, and biomectin, the mean of total life span and developmental times of females of F1 generation of female and male were significantly affected when compared to control females and males, respectively (Table 2).

The adult female longevity of offspring from females exposed to LC_{25} of penny and biomectin acaricides was shorter than that of control and females treated with agnar. The LC_{25} of biomectin significantly decreased the adult pre-oviposition period (APOP), while the total pre-oviposition period (TPOP) of *T. urticae* was significantly affected when female mites exposed to LC_{25} of penny.

The oviposition period of female offspring from females exposed to LC_{25} of agnar, penny and biomectin was shorter than that of untreated mites. This period was shortened from 11.09 days in control to only 8.72, 7.10, and 7.29 days, respectively.

On the other hand, the tested pesticides showed an adverse effect on daily fecundity. Therefore, total fecundity per female was decreased from 40.09 eggs / female in control to 14.94, 11.42, and 10.29 eggs/female treated with LC_{25} of these pesticides, respectively (Table 2). The current findings indicate that agnar, penny, and biomectin at sublethal concentrations may influence the durability of adult stages, longevity, and biological parameters of *T. urticae*.

Table 2. Mean (±SEM) development time, longevity and total life span (days) of offspring from females of *Tetranychus urticae* treated with LC_{25} of three pesticides.

Sex	Duration of developmental stages / days			
	Treatments			
Female	**Agnar**	**Penny**	**Biomectin**	**Control**
Egg	4.33± 0.16a	4.63± 0.15a	4.53± 0.12a	4.24± 0.16a
Larva	1.89± 0.16a	2.05± 0.14a	2.0±0.08a	1.76± 0.17a
Nymph	5.00± 0.24ab	5.47± 0.27a	5.06± 0.16ab	4.71± 0.16b
pre-adult	11.22± 0.32bc	12.16± 0.34a	11.59± 0.22ab	10.71± 0.32c
APOP	1.33± 0.11ab	1.53± 0.12a	1.12±0.07b	1.33± 0.10ab
TPOP	12.55± 0.36b	13.68± 0.33a	12.71± 0.26b	12.05± 0.34b
Oviposition	8.72± 0.68b	7.10± 0.36c	7.29± 0.36c	11.09± 0.41a
Longevity	11.22± 0.59b	9.84± 0.38c	9.47± 0.37c	14.14± 0.63a
Life span	22.44± 0.76b	22.00± 0.52b	21.06± 0.52b	24.86± 0.74a
Fecundity	14.94± 1.53b	11.42± 1.20bc	10.29± 0.57c	40.09± 2.50a
Male				
Egg	4.09± 0.20a	4.25± 0.25a	4.43± 0.21a	3.89± 0.26a
Larva	1.82± 0.18a	1.87± 0.12a	2.00 0.22a	1.67± 0.23a
Nymph	4.45± 0.24ab	5.12± 0.40a	4.43± 0.31ab	4.11± 0.31b
pre-adult	10.36± 0.40ab	11.25± 0.68a	10.86± 0.49ab	9.67± 0.37b
Longevity	10.54± 0.54b	9.87± 0.49b	9.85± 0.62b	14.00± 0.37a
Life span	20.91± 0.84b	21.12± 0.62b	20.71± 1.00b	23.67± 0.49a

Means in each row with the same letters are not significantly different (Paired bootstrap test, $P \leq 0.05$).

Population parameters

The population parameters of offspring from mite females treated with LC_{25} of agnar, penny and biomectin are presented in Table (3). Results showed that exposure of females to these acaricides reduced the net (R_0) and gross (GRR) reproductive rates compared to control. Consequently, the intrinsic (r) and finite (λ) rates of increase were affected. The tested acaricides had no effect on the mean generation time (T) of *T. urticae* (Table 3).

The tested acaricides significantly decreased the values of the intrinsic rate of increase (r) which was 0.129, 0.113 and 0.107 day^{-1} for females treated with agnar, penny and biomectin as compared to the control (0.199 day^{-1}), respectively. These results revealed that the sublethal concentration of these acaricides affected the adult longevity, total fecundity and all biological parameters of *T. urticae*.

Table 3. Life table parameters (Mean ± SE) of offspring from females of *Tetranychus urticae* treated with LC_{25} of three pesticides.

Life table parameters	Agnar	Penny	Biomectin	Control
Intrinsic rate of increase (r_m)	0.129 ±0.01b	0.113 ±0.01b	0.107 ±0.01b	0.199 ±0.01a
Finite rate of increase (λ)	1.138 ±0.01b	1.120± 0.01b	1.113 ±0.01b	1.220 ±0.01a
Net reproductive rate (R_0)	8.97 ±1.61b	7.23± 1.25b	5.83 ± 0.98b	28.07 ±3.78a
Gross reproductive rate (GRR)	13.78 ± 2.33b	9.60 ± 1.53b	8.67 ± 1.29b	31.37 ± 4.06a
Mean generation time (T)	16.96 ± 0.53a	17.45 ± 0.40a	16.54 ± 0.37a	16.76 ± 0.38a

Means in each row with the same letters are not significantly different (Paired bootstrap test, $P \leq 0.05$).

Survivorship and fecundity

The TSSM age-stage specific survival rate (S_{xj}) represents the likelihood that a newly born individual would live to the age-stage unit age x and stage j (Fig. 2). The likelihood of newly emerged larvae surviving until adulthood was higher in the control (0.70 for females and 0.30 for males) than in agnar, penny and biomectin treatments (0.60, 0.63 and 0.57 for females and 0.37, 0.27 and 0.23 for males, respectively).

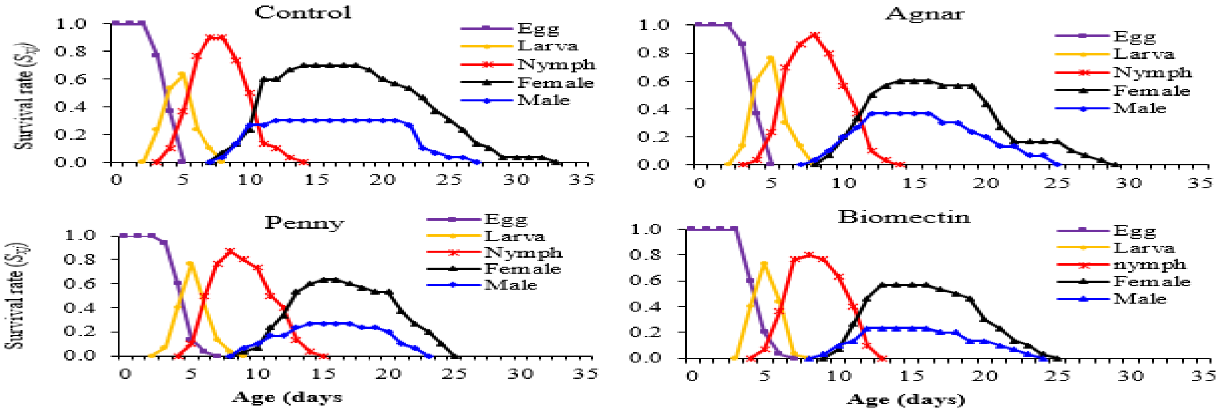

Fig. 2. Age-stage survival rate (S_{xj}) of offspring of *Tetranychus urticae* females treated with LC_{25} of agnar, penny and biomectin acaricides compared with control.

The age-specific survivorship (l_x) until age18, 7, 5, and 5 days in control, agnar, penny and biomectin, respectively remained as high as 1.0. The treated group with biomectin of *T. urticae* had the lowest survival rate of all age stages. Also, the spider mite treated with biomectin had the lowest peak of m_x (Fig. 3). The highest values of m_x were observed on the 16th day of the life span, which were 3.33 eggs/female/day in control group, while they were decreased to 1.28, 1.46 and 1.17 eggs/female/day on 16th, 17th and 15th day of the female life span treated with agnar, penny and biomectin acaricides, respectively. The mean number of offspring, which produced by *T. urticae* individuals of the age *x* and stage *j* per day (f_{xj}) is shown in Fig. (3). Oviposition started on control, agnar, penny and biomectin after 9, 10, 10 and 11 days, respectively. The highest daily fecundity of spider mite was 4.76 eggs in the control occurred at the age of 16th day, while they were decreased to 2.09, 2.11, and 1.65 eggs at the age of 16th, 17th and 15th days, respectively. The $l_x m_x$ showed similar trend as m_x (Fig. 3).

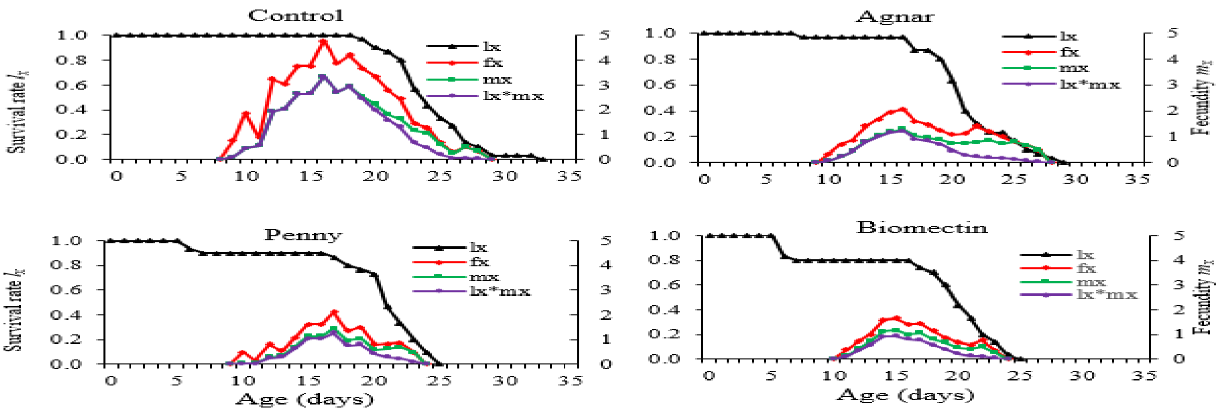

Fig. 3. Age-specific survival rate (l_x), age-stage fecundity of female (f_{xj}) and age-specific fecundity rate (m_x) of offspring of *Tetranychus urticae* females treated with LC_{25} of agnar, penny and biomectin acaricides compared with control.

The v_{xj} value describes an individual's contribution to the future population at age *x* and stage *j*. Figure 4 shows the age-specific reproductive values (v_x) of spider mites in the control and the tested acaricides. The spider mite treated with LC_{25} of these acaricides had lower reproductive values than the control. For mites treated with agnar, penny and biomectin, the v_{xj} values decreased to 5.40, 5.23 and 4.94 at age 13th, 14th and 13th days, respectively compared with untreated control it was 12.21 at age 14th days.

Any negative effects other than mortality, such as diminished feeding, poorer fecundity or egg viability, reduced longevity, or increased development time, and altered sex ratios, are all examples of sublethal impacts (Biondi *et al.*, 2013 and Beers and Schmidt, 2014). They are crucial for determining the overall impact of pesticides on mites (Parsaeyan *et al.*, 2017). Life table analysis is one of the best methods to assess the effects of pesticides on an organism (Kim *et al.*, 2004).

The results demonstrated that LC_{25} of tested acaricides can diminish survival rate, oviposition period, longevity, and fecundity of *T. urticae* females. Several studies have been conducted to investigate the effects of pesticides on *T. urticae*. For examples, Saber *et al.* (2018) who found that the reproductive capacity of *T. urticae* can be significantly affected by sublethal concentrations (LC_{25}) of spirodiclofen, abamectin and pyridaben acaricides. Also, Marcic (2007) stated that spirodiclofen at sublethal concentrations/doses reduced the survival rate and other life-table parameters of *T. urticae.*

The present results referred to agnar, penny and biomectin had a negative effect on life table parameters of *T. urticae*. The concentrations (LC_{25}) of selected pesticides could reduce the survival rate, oviposition period, longevity, and fecundity of this spider mite female (Table 2). Pesticides have been shown to have sublethal effects on *T. urticae* population parameters by several research (Marcic, 2007; Alinejad *et al.*, 2014; Abdel-Rahman and Ahmed, 2018; Saber *et al.*, 2018 and Abdel-Rahman, 2019). These studies support our findings regarding the effects of pesticides on *T. urticae* development, survival, and reproduction.

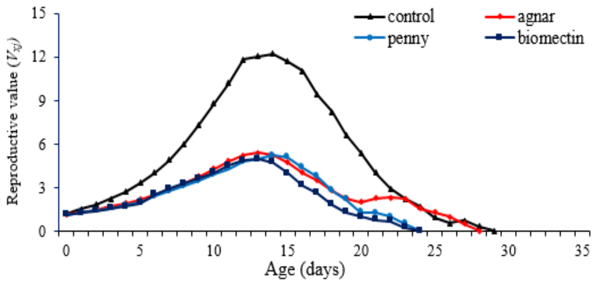

Fig. 4. Age-stage reproductive value (v_{xj}) of offspring of *Tetranychus urticae* females treated with LC_{25} of agnar, penny and biomectin acaricides compared with control.

Furthermore, the results revealed that the LC_{25} of tested acaricides affected the population parameters (i.e., r_m, λ, R_0, and *GRR*) for *T. urticae* because of negative effects on adult developmental time, reproduction period and fecundity. The intrinsic rate of increase (r_m) is the best factor for evaluating pesticide effects on pests (Hamedi *et al.*, 2010), because it demonstrates the total effects on survival and fertility (Li *et al.*, 2017). The results of this study revealed that the tested acaricides reduced r_m, λ, R_0, and *GRR* of *T. urticae* when compared to the control, demonstrating that acaricides had a negative impact on these parameters. Similar pesticides effects on TSSM life history traits were observed by (Alinejad *et al.*, 2014; Li *et al.*, 2017; Abdel-Rahman and Ahmed, 2018; Saber *et al.*, 2018) reported that the r_m, λ and R_0 values for offspring of mites treated with acaricides were significantly decreased. Moreover, Alinejad *et al.* (2014) and Saber *et al.* (2018) The survival rate curve showed significant instar overlap due to the varying growth rates seen among *T. urticae* individuals. This is consistent with our results.

Also, in this study, the age-specific survival rate (l_x), age-specific fecundity rate (m_x), age-stage fecundity of female (f_{xj}) and age-specific maternity (l_xm_x) values of *T. urticae* treated with LC_{25} of agnar, penny and biomectin were influenced variably (Fig. 3). in agreement with results of Marcic (2007) Saber *et al.* (2018) and Abdel-Rahman (2019) noted that the tested acaricides significantly reduced mite growth. *T. urticae* the reproductive value (v_{xj}) was affected by acaricides Saber *et al.* (2018). Similar findings were found in this study, with acaricide-treated mites having a lower age-specific reproductive (v_{xj}) value than untreated mites. The low dosages of pesticides in may have considerable effects on population levels and may affect *T. urticae* population dynamics. (Stark and Banks, 2003). According to our results, the sublethal concentration (LC_{25}) of the studied acaricides had detrimental impacts on survivability and life-table parameters of the future generation of the two-spotted spider mite.

Evaluation of growth and productivity characteristics of climbed bean plants

The vegetative growth of climbed bean plants such as plant height, number of leaves per plant and chlorophyll content were variably influenced by using three acaracides with or without *P. persimilis* to control *T. urticae* during two successive seasons (Table 4).

The highest plant height was recorded using the acaricides penny and biomectin with *P. persimilis* as a co-treatment. It recorded 181.3 & 170.5 cm and 190.4 & 179.0 cm during 2018/2019 and 2019/2020, respectively. Followed by *P. persimilis* as a single treatment, it recorded 166.6 and 174.9 cm during both seasons, respectively. Whereas when the acaricides were used alone, they recorded moderate plant height compared with the combined treatments. While the lowest plant height was recorded with control.

Also, the highest number of leaves per plant recorded with penny and biomectin acaricides with *P. persimilis* as and combined treatments, while the lowest number of leaves/ plant recorded with biomectin alone and control during both seasons (Table 4). The chlorophyll content showed similar trend as the plant height. Also, the used of the predatory mite with acaricide as a combine treatment was found to be significantly higher effect on number of pods/plant, pod weight (g) and total yield (g) than the use of acaricide alone.

The results of the study showed that when combined the acaricide penny or biomectin with *P. persimilis* as a co-treatment significantly increased vegetative growth compared with control.

Table 4. Effect of three acaricides with or without *Phytoseiulus persimilis* in controlling TSSM on growth and productivity characteristics of climbed bean plants

Treatments	Plant height (cm)	No. of leaves /plant.	Chlorophyll (SPAD)	No. of pods /plant	Pod weight (g)	Total yield (g)
			Season 2018/2019			
Control	118.5g	16.67f	34.07f	52.8f	7.00g	5576g
P. persimilis	166.6c	20.70c	37.58c	59.0a	7.83d	6969c
Agnar	162.2d	21.70b	37.17d	56.7c	7.76d	6641d
Penny	158.7e	19.00e	37.2d	55.7d	7.63e	6415e
Biomectin	155.3f	16.67f	36.37e	53.4e	7.40f	5953f
Agnar+*P. persimilis*	163.0d	19.83d	37.37cd	58.6b	8.10c	7151c
Penny+*P. persimilis*	170.5b	22.33a	38.9b	59.3a	8.27b	7385b
Biomectin+*P. persimilis*	181.3a	22.67a	40.42a	58.4b	8.73a	7681a
LSD 0.05	2.650	0.3589	0.2656	0.3756	0.09592	206.7
			Season 2019/2020			
Control	124.4g	15.9g	32.45f	50.3f	6.67h	5311g
P. persimilis	174.9c	19.7d	35.79c	56.2a	7.50d	6637c
Agnar	170.3d	20.6c	35.4d	54.0c	7.40e	6325d
Penny	166.6e	18.1f	35.43d	53.1d	7.30f	6110e
Biomectin	163.1f	15.9g	34.64e	50.8e	7.03g	5669f
Agnar+*P. persimilis*	171.1d	18.87e	35.59cd	55.8b	7.73c	6811c
Penny+*P. persimilis*	179.0b	21.27b	37.05b	56.5a	7.87b	7033b
Biomectin+*P. persimilis*	190.4a	21.6a	38.5a	55.6b	8.30a	7315a
LSD 0.05	2.772	0.3323	0.2538	0.3631	0.09592	196.8

Means within a column followed by the same letter are not significantly different (LSD test: $P < 0.05$ according to Snedecor and Cochran 1980).

Pod quality characteristics

The pod quality characteristics of climbed bean plants such as total soluble solids (TSS), vitamin C, total chlorophyll and the total carbohydrates were significantly affected by using three acaracides with or without *P. persimilis* to controlling *T. urticae* during two successive seasons (Table 5). When combined penny or biomectin acaricide with *P. persimilis* as a co-treatment significantly increased of (TSS), vitamin C, total chlorophyll and the total carbohydrates compared with other treatments.

Our finding the results, the acaricides application could be successfully integrated with the predator mite, *P. persimilis* in controlling *T. urticae* in climbed bean plants, resulting in improved growth and productivity characteristics. This may be due to reducing the effect of spraying acaricides on plants, in addition to reducing *T. urticae* infestation to a level below the level of economic damage. Therefore, when controlling this mite, growing beans are protected, thereby enhancing greater productivity. These outcomes are consistent with those reported by Nwadinigwe (2010) who indicates that lambda-cyhalothrin decrease insect population assault and may improve crop growth, development, and yield.

Table 5. Effect of three acaricides with or without *Phytoseiulus persimilis* in controlling TSSM on pod quality characteristics of climbed bean plants.

Treatments	TSS	Vitamin C	Total Chlorophyll	Total Carbohydrate
Season 2018/2019				
Control	5.07g	15.00h	50.02g	21.52f
P. persimilis	5.56d	16.80c	51.73c	23.41c
Agnar	5.21f	16.00e	51.41e	23.40c
Penny	5.34e	15.80f	51.62cd	22.55e
Biomectin	5.22f	15.40g	50.71f	21.34f
Agnar + *P. persimilis*	5.71c	16.60d	51.54de	23.13d
Penny + *P. persimilis*	6.00b	17.00b	53.04b	25.20b
Biomectin + *P. persimilis*	6.15a	17.50a	53.67a	26.30a
LSD 0.05	0.05538	0.1356	0.1661	0.2477
Season 2019/2020				
Control	4.83g	14.30h	47.64g	20.50f
P. persimilis	5.29d	16.00c	49.27c	22.30c
Agnar	4.96f	15.23e	48.96e	22.29c
Penny	5.34e	15.80f	51.62cd	22.55e
Biomectin	4.97f	14.70g	48.30f	20.32f
Agnar + *P. persimilis*	5.44c	15.8d	49.09de	22.03d
Penny + *P. persimilis*	5.71b	16.20b	50.51b	24.00b
Biomectin + *P. persimilis*	5.85a	16.67a	51.11a	25.05a
LSD 0.05	0.05538	0.09592	0.1661	0.2349

Means within a column followed by the same letter are not significantly different (LSD test: $P < 0.05$ according to Snedecor and Cochran 1980).

CONCLUSION

Biomectin or penny combined with the predatory mite *P. persimilis* were more effective in controlling *T. urticae* than acaricides or *P. persimilis* alone. *T. urticae* biological characteristics including as developmental time, survival rate, and fecundity were significantly affected by the acaricides studied. Furthermore, the net (R_0) and gross (*GRR*) reproductive rates of females treated with agnar, penny and biomectin at LC_{25} significantly reduced. Consequently, the intrinsic (r_m) and finite (λ) rates of increase were affected. Therefore, acaricides application could be successfully integrated with *P. persimilis* to reduce *T. urticae* infestation by acaricides spray before the predator release. But acaricides should be used carefully so that they are sprayed a week or two before the release of the predator to get rid of the remaining effect, and employ acaricides with short residual activity, selective acaricides, and pesticide-tolerant predators.

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تكامل المبيدات الأكاروسية مع *Phytoseiulus persimilis* للتحكم في *Tetranychus urticae* على نباتات الفاصوليا ، وتأثيرها شبه المميت على معلمات جدول حياته

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تعتبر الفاصوليا المتسلقة (.*Phaseolus vulgaris* L) من محاصيل الخضار التصديرية ذات الأهمية الاقتصادية. الفاصوليا المزروعة في الصوب البلاستيكية تصاب بشدة بالعنكبوت الأحمر ذو النقطتين (TSSM)، *Tetranychus urticae* Koch (Acari: Tetranychidae). تهدف الدراسة الحالية إلى تقييم الفعالية الحقلية لثلاثة مبيدات أكاروسية مع أو بدون المفترس االأكاروسي، *Phytoseiulus persimilis* Athias-Henriot ضد *T. urticae* على الفاصوليا المتسلقة تحت ظروف الدفيئة مع الإشارة إلى خصائص النمو والإنتاجية. أظهرت نتائج الفعالية الحقلية أن تطبيق استخدام المبيدات الأكاروسية ؛ الأجنر والبيني و البيومكتين جنبًا إلى جنب مع المفترس الأكاروسي *P. persimilis* أكثر فاعلية في السيطرة علي العنكبوت الأحمر ذي البقعتين (TSSM) من تطبيق استخدام المبيدات الأكاروسية أو المفترس الأكاروسي بشكل منفصل. كما كان مبيد البيني او البيومكتين مع المفترس الأكاروسي كمعاملة مزدوجة اعطت زيادة في النمو والأنتاجية للفاصوليا أيضا ، تم تقييم تأثير التركيز تحت المميت (LC_{25}) لهذه المبيدات على معايير جدول الحياة لإناث *T. urticae* تحت الظروف المعملية وأظهرت جميع المبيدات تأثيرا معنويا على المعايير البيولوجية ل *T. urticae* بما في ذلك زمن التطور ومعدل البقاء على قيد الحياة والخصوبة. أظهرت الإناث التي عولجت بمبيد الأجنر والبيني والبيومكتين عند LC_{25} انخفاضًا كبيرًا في معدلات التكاثر الصافية (R_0) والإجمالية (*GRR*) وبالتالي ، تأثرت معدلات الزيادة الجوهرية (r_m) والمحدودة (λ). حيث كان المعدل الجوهري للزيادة (r_m) في المجموعات المعالجة والمجموعة الضابطة 0.129 و 0.113 و 0.107 و 0.199 أنثى لكل أنثى في اليوم على التوالي. أشارت النتائج إلى أن الجمع بين دراسة الفعالية الحقلية للمبيدات الأكاروسية وكذلك التأثيرات شبه المميتة لها على معلمات جدول الحياة لـ *T. urticae* تسمح لنا بالحصول على صورة واضحة عن استجابات العنكبوت الأحمر لهذه المبيدات لامكانية دمجها في برامج المكافحة المتكاملة له.