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Article

How Spiromesifen affects some biological parameters and switching behavior of predatory mite *Amblyseius swirskii* (Acari: Phytoseiidae) when feeding on different ratios of mixed preys

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ABSTRACT

Two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) and silverleaf whitefly, *Bemisia tabaci* (Gennadius) (Hem.: Aleyrodidae) are among the most destructive pests under greenhouse conditions which is primirarily countered using chemical pesticides. Due to insecticidal and acaricidal effectiveness of Spiromesifen (Oberon®), agricultural producers extensively used this chemical to control both whitefly and spider mite populations. In the present study, effects of recommended concentration of Spiromesifen on some biological and behavioral attributes of predatory mite *Amblyseius swirskii* Athias-Henriot (Acari: Phytoseiidae) feeding on different ratios of two-spotted spider mite and silverleaf whitefly were investigated. Different treatments were defined as 1 (150 immature stages of mite + 0 immature stages of whitefly), 2 (120 mite + 30 whitefly), 3 (90 mite + 60 whitefly), 4 (75 mite + 75 whitefly), 5 (60 mite + 90 whitefly), 6 (30 mite + 120 whitefly) and 7 (0 mite + 150 whitefly). According to the results, mortality percentage of adult individuals was not significantly affected by different ratios of prey. With increasing ratio of preys tested in experimental arena, feeding activity of predatory mite on both preys was increased. However, in the case of *T. urtice*, linear relation observed between the initial number of mite offered and number of mite eaten was more significant. Reproductive responses of female predators to different ratios of mixed preys had no specified trend. Furthermore, switching behavior was not detected in female predators. Our results have considerable role for increasing biological efficacy of *A. swirskii* in integrated management programs of different pests.

KEY WORDS: Biological control; chemical control; predatory mites; spider mites; whiteflies.

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INTRODUCTION

Plant cultivation under greenhouse conditions provides favorable environments for development of insect and mite pests. Spider mites, whiteflies, aphids and thrips are recognized as the most important phytophagous pests feeding on different host plants including strawberry, tomato, cucumber, pepper, eggplant, rose flower, etc. (Khanjani 2013). Among these destructive organisms, two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) and silverleaf whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) are extreme economic pests for many crops worldwide and cause considerable crop loss (Gerling 1990; Park and Lee 2005).

Tetranychus urticae has a wide host range and its populations have increased enormously in different parts around the world both in indoor and outdoor conditions (Tsagkarakou *et al*. 2002;

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Sedaratian *et al.* 2009; 2011). Feeding activity of this mite pest concentrates underside of plant's leaves and coincides with production of profuse web (Helle and Sabelis 1985). Using a piercing-sucking mechanism, *T. urticae* damages plant cells and sucks their chlorophyll content. This feeding behavior leads to formation of yellow spots on leaves surface (Martinez-Ferrer *et al.* 2006) and restricts successful production in different cropping systems (Nyoike and Liburd 2013). In addition to *T. urticae*, *B. tabaci* is another destructive pest in greenhouse conditions which causes severe damage to its host plants (Oliveira *et al.* 2001). Whiteflies could directly damage plants by sucking their sap (Musa and Ren 2005) or indirectly by transmission of plant viruses (Jones 2003). Another problem is excretion of honeydew by both nymph and adult individuals (Palumbo *et al.* 2000). These compounds provide appropriate conditions for growth of sooty moulds and significantly decrease photosynthesis and efficiency of chemical pesticides (Gerling *et al.* 1980). However, agricultural producers face both *T. urticae* and *B. tabaci* in most greenhouse cultivations and considerable measures are taken to suppress their populations (Heydari *et al.* 2016).

The most applied strategy for suppressing populations of *T. urticae* and *B. tabaci* is chemical pesticides. Several issues such as short life span, rapid developmental rate, high reproductive potential and ability to develop resistance to synthetic pesticides have made chemical control of these arthropod pests particularly difficult (Luczynski *et al.* 1990; Horowitz and Ishaaya 1995). On the other hand, high reliance on these compounds has various detrimental outcomes such as negative effects on non-target organisms, environment and human health (Bielza *et al.* 2009). However, to minimize negative effects and maximize efficiency, an attitude change in chemical control of phytophagous pests in agro-ecosystems is urgently needed (Opit *et al.* 2001; Naher *et al.* 2006).

To overcome populations of undesirable pests, agricultural producers permanently explore pesticides with new modes of action. In recent years, synthesized chemicals which have both insecticidal and acaricidal properties like Spiromesifen (Oberon®) are extremely preferred by plant growers. In fact, such compounds decrease the number of separate sprays needed for different pests and hence, reduce expense of pest management programs. Spiromesifen is a spirocyclic phenyl-substituted tetronic acid derivative with insecticidal (*Bemisia* and *Trialeurodes* spp.) and acaricidal (*Tetranychus* and *Panonychus* spp.) activity for both greenhouse and open field applications (Nauen *et al.* 2005). With a novel mode of action, this compound inhibits biosynthesis of lipids and causes noticeable reduction in adult fecundity. Furthermore, Spiromesifen also disrupts development of immature stages (Palumbo 2004). Fanigliulo *et al.* (2010) evaluated effects of Spiromesifen on populations of *B. tabaci* and *T. urticae* on *Capsicum annuum* L. and demonstrated remarkable efficiency of this chemical compound for controlling both mite and whitefly in the field conditions. In another study, Alam *et al.* (2014) confirmed reliable efficiency of Spiromesifen on spider mite and whitefly on tomato and also indicated no detectable toxicity to natural enemies.

In addition to new pesticides, biological control is also considered as a promising strategy for suppressing pest populations. However, in circumstances in which different pest species exist, application of polyphagous natural enemies could be noticed as a reliable option for regulating population density of co-existing organisms. *Amblyseius swirskii* Athias-Henriot (Acari: Phytoseiidae) is one of the most important predatory mites with predation activity on both *T. urticae* (El-Laithy and Fouly 1992; Momen and El-Saway 1993; Messelink *et al.* 2010) and *B. tabaci* (Calvo *et al.* 2011; van Lenteren 2012) as well as other species such as thrips (Wimmer *et al.* 2008; Arthurs *et al.* 2009), stored mites, small arthropods, honeydew and also plant resources such as pollen (Nguyen *et al.* 2015). Many of the pests that are consumed by *A. swirskii* can occur simultaneously in a crop (Messelink *et al.* 2010). Regarding feeding activity of *A. swirskii* on both spider mites and whiteflies, its application in situations in which these phytophagous pests are simultaneously activated could serve as promising option to regulate their population density below desirable level.

However, one of the main concerns about safety of chemical compounds used in pest management programs is their possible effects on natural enemies (Desneux *et al*. 2007; Ditillo *et al*. 2016). It is documented that compatibility of these compounds with natural enemies during their simultaneous application may create favorable conditions for successful implemention of integrated pest management programs. However, although Mortazavi *et al*. (2019) evaluated the effects of *T. urticae* and *Trialeurodes vaporariorum* Westwood on efficiency of *A. swirskii*, our knowledge about possible effects of mixed preys (*T. urticae* and *B. tabaci*) on biological performance of this predatory mite is so restricted. Our laboratory observations has revealed that this predatory mite has reliable potential to feed on both *T. urticae* and *B. tabaci* (unpublished data). Accordingly, the main objective of this study was evaluation of biological and behavioral responses of *A. swirskii* to different ratios of mixed preys (*T. urticae* and *B. tabaci*) treated with recommended concentrations of Spiromesifen.

MATERIALS AND METHODS

Plant cultivations

In the present study, cucumber (*Cucumis sativus* L.) leaves were used for both organisms rearing and experiments. For this, seeds of greenhouse cultivar of cucumber ‘Negin’ were obtained from Plant Protection Organization, Yasouj, Iran. This cultivar has considerable acceptance by commercial cucumber-growers. Seeds were sown in fertilized field soil (2:1 mix of soil: manure) in plastic pots (16 cm diameter and 20 cm height) under greenhouse conditions (25 ± 5 ºC, relative humidity of 65 ± 20% and natural photoperiod from spring to fall). During the experiments, all plants were watered at the same time and no pesticides or additional fertilizers used. Furthermore, plants were kept in net cages (1 × 1 × 1 m) to avoid infestations. When plants reached about 30 cm in height, they were used for colonization of *T. urticae* or *B. tabaci* and experiments.

Chemical pesticide

To perform the experiments, a commercial formulation of Spiromesifen (Oberon® SC 240, Bayer Crop Science) was applied. Since the recommended field concentration of Spiromesifen for whiteflies and spider mites were 400 and 500 ml/ha, respectively, an intermediate concentrations (450 ml/ha) was tested in the experiments. This concentration was based on the maximum label rate applied at 400 L/ha of water. Treatment was applied using a manual sprinkler set 20 cm away from the experimental arenas.

Rearing mites and whiteflies

Initial specimens of mites and whiteflies were originally collected from infected regions (field and greenhouse) of Yasouj. These specimens were separately placed in plastic bags and transferred into the laboratory. In the laboratory, to remove undesirable organisms, the collected specimens were carefully checked using a stereomicroscope and then transferred onto cucumber plants under greenhouse conditions. Each stock colony was separately kept at different mesh cages. During the experiments, dead plants were periodically replaced by new ones. Furthermore, the colonies were supplemented with new specimens collected from the above-mentioned regions. Before experiments, these colonies were reared under greenhouse conditions (25 ± 5 ºC, 65 ± 20% R.H. and natural photoperiod from spring to fall) for at least four generations.

Predatory mite

The colony of *A. swirskii* was provided by Giah Bazr Alvand Company, formal agent of Koppert Company in Iran. Rearing arena was constructed from a 15 × 20 cm clear plastic sheet resting on water-saturated foam in a plastic pan (25 × 40 cm). The edges of the clear plastic sheet were covered with strips of tissue paper immersed in water in the plastic pan to prevent predatory mites from escaping (McMurtry and Scriven 1965). Infested cucumber leaves which have mixed mite and whitefly populations were provided for predators. Furthermore, maize pollen was added to rearing arena as supplementary food.

Experimental protocols

All experiments were performed under controlled laboratory conditions at 25 ± 1 ºC, 65 ± 5% R.H. and a light period of 14L: 10D hours. Furthermore, to accomplish the experiments, the Munger cage was used. This cage was constructed from three glass sheets (10 × 12 × 0.4 cm). The lower and upper sheets have no holes and the median sheet has four holes (2.50 cm diameter). A layer of water-saturated tissue paper was placed on the lower sheet and detached cucumber leaves were put on it. Then, the median sheet was placed on cucumber leave and the higher glass sheet covers it. This set was assembled by four paper clips. Each set provides four experimental arenas for our experiments.

In the present study, seven ratios of mixed *T. urticae* and *B. tabaci* were prepared. These ratios were defined as 100T + 0B (100% immature stages of mite + 0% immature stages of whitefly), 80T + 20B (80% mite + 20% whitefly), 60T + 40B (60% mite + 40% whitefly), 50T + 50B (50% mite + 50% whitefly), 40T + 60B (40% mite + 60% whitefly), 20T + 80B (20% mite + 80% whitefly) and 0T + 100B (0% mite + 100% whitefly). In fact, we considered two extremes for both preys as control (100%T + 0%B and 0%T + 100%B). To prepare these ratios, immature stages of both preys were used. In the case of *T. urticae* larva and protonymph stages and for *T. tabaci*, newly hatched nymphs (i.e., crawlers) were selected. Furthermore, total number of prey in each ratio was 150 individuals. Accordingly, percentage of 100, 80, 60, 50, 40, 20 and 0 corresponded to 150, 120, 90, 75, 60, 30 and 0 preys, respectively.

For each ratio, six replications were considered and transferred into Munger cages. Then, 10 female predators (24 h age) were introduced to each cage. These predators were allowed to feed on different ratios for three consequent days. After this, the arena was sprayed with recommended concentration of Spiromesifen and left at room temperature to dry for 60 min. Predators were feed on treated ratios for three consequent days. Every day, the number of preys eaten (*T. urticae* and *B. tabaci*) were carefully checked and predators transferred into a new cage provided with treated preys at same ratio. To provide natural conditions and maintain the predatory mites on treated leaves, these new cages were sprayed at the beginning of experiments and kept in growth chamber until their usage. In addition, the number of laid eggs was also recorded.

Mortality percentage, consumption rate and fecundity of predatory mite on different ratios of preys were analyzed using One-Way ANOVA. For this analysis, the SAS software (SAS 9.4) was applied. Mean grouping was performed by SNK test ($P < 0.05$). All graphs were drawn by Excel software.

Switching behavior

Recorded data in above-explained experiments were used to investigate switching behavior of predatory mite *A. swirskii*. In the first step, the value of Manly's beta index (β) for predatory mite at different ratios of prey was calculated by following equation (Manly *et al.* 1972):

$$\beta_1 = \log (e_1/A_1) / \log (e_1/A_1) + \log (e_2/A_2)$$

where e_1 and e_2 are the number of alive mites and whiteflies at the end of experiment, respectively. Furthermore, A_1 and A_2 present initial number of each prey at the beginning of switching assay, respectively. In the second step, the linear regression between proportion of mite to all preys (mite + whitefly) and preference index (β) of predatory mite was investigated (Heydari *et al.* 2016; Moradi *et al.* 2019).

RESULTS

Mortality

Table 1 presents mortality percentage of female individuals of predatory mite *A. swirskii* when feeding on different ratios of mixed prey treated with recommended concentration of Spiromesifen. Our findings revealed that feeding on different mixes has no significant effects on mortality of female predators in three consequent days.

Prey consumption

Our findings revealed that predatory mite had the higher feeding activity on *T. urticae* than *B. tabaci*. Consumption of *A. swirskii* from immature stages of *B. tabaci* at different ratios of prey is exhibited in Table 2. With one exception (third day), the results obtained revealed that increasing ratio of *B. tabaci* in experimental arena significantly increased number of preys eaten by female predators. Accordingly, the highest value of *B. tabaci* eaten by female predators was recorded at highest ratios of this prey (20T + 80B and 0T + 100B).

Like *B. tabaci*, increasing initial number of prey in experimental arena significantly increased consumption of *A. swirskii* from *T. urticae* (Table 3). However, comparison of consumption rate of predatory mite *A. swirskii* from *T. urticae* and *B. tabaci* (Tables 2, 3), obviously revealed that this predator had higher consumption on *T. urticae*.

Table 1. Effects of recommended concentration of Spiromesifen on mortality (mean ± SE) of predatory mite *Amblyseius swirskii* feeding different ratios of mixed prey.

Different ratios of prey*	**Days**			
	1st	**2nd**	**3rd**	**Total**
100T + 0B	1.34 ± 0.63^{a}	1.21 ± 0.51^{a}	0.71 ± 0.00^{a}	2.60 ± 0.68^{a}
80T + 20B	1.72 ± 0.62^{a}	1.21 ± 0.51^{a}	1.55 ± 0.53^{a}	3.10 ± 0.79^{a}
60T + 40B	1.21 ± 0.51^{a}	1.55 ± 0.53^{a}	1.55 ± 0.53^{a}	4.11 ± 1.01^{a}
50T + 50B	0.71 ± 0.00^{a}	1.55 ± 0.53^{a}	1.97 ± 0.57^{a}	4.23 ± 0.78^{a}
40T + 60B	1.12 ± 0.42^{a}	1.97 ± 0.73^{a}	1.97 ± 0.57^{a}	4.42 ± 0.75^{a}
20T + 80B	1.34 ± 0.64^{a}	2.40 ± 0.78^{a}	2.40 ± 0.78^{a}	6.15 ± 1.11^{a}
0T + 100B	1.13 ± 0.42^{a}	2.29 ± 0.95^{a}	2.23 ± 0.93^{a}	4.52 ± 1.27^{a}
F	0.39	0.56	0.89	1.23
P	0.8784	0.7599	0.5139	0.3149

[*] T and B indicate *Tetranychus urticae* and *Bemisia tabaci* and percentage of 100, 80, 60, 50, 40, 20 and 0 corresponded to 150, 120, 90, 75, 60, 30 and 0 preys, respectively.
[**] Different letters in a same column revealed significant differences ($P < 0.05$, SNK).

Fecundity

Fecundity of predatory mite *A. swirskii* at different ratios of prey is presented at Table 4. As shown, reproductive responses of female predators to different treatments had no specified trend. However, in different days, the highest fecundity was recorded at ratio of 20T + 80B (20% *T. urticae* and 80% *B. tabaci*). Furthermore, the highest value of total fecundity of predatory mite was also calculated at this ratio.

Regression analysis

Figure 1 reveals the relationship between initial number of prey (*B. tabaci* or *T. urticae*) and number of individuals eaten by female predators. The results obtained revealed linear relationship for *T. urticae* at different days. In other words, with increasing initial number of mite offered in experimental arena, the number of individuals eaten by female predators was linearly increased. This linear relationship was statistically approved.

Table 2. Effects of recommended concentration of Spiromesifen on *Bemisia tabaci* eaten (mean ± SE) by predatory mite *Amblyseius swirskii* at different ratios of mixed prey.

Different ratios of prey[*]	**Days**			
	1st	**2nd**	**3rd**	**Total**
80T + 20B	14.50 ± 4.68^{d}	13.83 ± 3.54^{d}	14.00 ± 3.37^{d}	42.33 ± 9.67^{c}
60T + 40B	23.00 ± 6.42^{cd}	27.33 ± 4.88^{c}	23.17 ± 6.07^{c}	73.50 ± 6.86^{bc}
50T + 50B	38.00 ± 8.37^{c}	42.67 ± 11.37^{b}	39.00 ± 5.16^{b}	116.00 ± 10.71^{b}
40T + 60B	33.33 ± 8.69^{c}	43.00 ± 6.28^{b}	40.17 ± 9.53^{b}	117.60 ± 22.81^{b}
20T + 80B	52.60 ± 15.34^{b}	43.20 ± 11.39^{b}	52.67 ± 3.77^{a}	141.33 ± 19.50^{b}
0T + 100B	100.67 ± 3.56^{a}	59.25 ± 6.50^{a}	34.75 ± 5.72^{b}	198.33 ± 16.68^{a}
F	80.32	20.13	28.50	29.76
P	0.000	0.000	0.000	0.000

[*] T and B indicate *Tetranychus urticae* and *Bemisia tabaci* and percentage of 100, 80, 60, 50, 40, 20 and 0 corresponded to 150, 120, 90, 75, 60, 30 and 0 preys, respectively.

[**] Different letters in a column revealed significant differences ($P < 0.05$, SNK).

In the case of *B. tabaci*, although with increasing initial number of preys offered the consumption rate was increased, in comparison with *T. urticae* the observed relationship was less sever. Higher *P* value together with lower $R^{2}adj$ confirmed this statement. However, in 3rd day, no linear relationship was detected.

Table 3. Effects of recommended concentration of Spiromesifen on *Tetranychus urticae* eaten (mean ± SE) by predatory mite *Amblyseius swirskii* at different ratios of mixed prey.

Different ratios of prey[*]	**Days**			
	1st	**2nd**	**3rd**	**Total**
100T + 0B	146.67 ± 1.10^{a}	148.00 ± 1.26^{a}	138.17 ± 4.17^{a}	432.83 ± 5.42^{a}
80T + 20B	107.75 ± 1.93^{b}	111.17 ± 2.84^{b}	117.00 ± 0.82^{b}	300.00 ± 21.30^{b}
60T + 40B	86.33 ± 1.08^{c}	85.50 ± 1.86^{c}	87.83 ± 0.70^{c}	259.67 ± 2.08^{c}
50T + 50B	74.17 ± 0.40^{d}	73.67 ± 1.14^{d}	68.50 ± 4.25^{d}	216.33 ± 5.44^{d}
40T + 60B	58.67 ± 0.42^{e}	57.50 ± 0.99^{e}	54.67 ± 3.67^{e}	170.83 ± 3.72^{e}
20T + 80B	28.83 ± 0.54^{f}	28.83 ± 0.54^{f}	29.67 ± 0.33^{f}	87.33 ± 0.95^{f}
F	1988.78	662.69	193.41	157.28
P	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[*] T and B indicate *Tetranychus urticae* and *Bemisia tabaci* and percentage of 100, 80, 60, 50, 40, 20 and 0 corresponded to 150, 120, 90, 75, 60, 30 and 0 preys, respectively.

[**] Different letters in a same column revealed significant differences ($P < 0.05$, SNK).

Switching behavior

Figure 2 shows the results of switching experiments in female individuals of *A. swirskii*. The results obtained revealed that this predatory mite has no switching behavior from immature stages of *T. urticae* to *B. tabaci* and the linear relationship between proportion of mite and preference index (β) of *A. swirskii* was not statistically significant ($P = 0.329$).

Table 4. Effects of recommended concentration of Spiromesifen on fecundity (mean ± SE) of predatory mite *Amblyseius swirskii* feeding on different ratios of mixed prey.

Different ratios of prey*	**Days**			
	1st	**2nd**	**3rd**	**Total**
100T + 0B	9.83 ± 1.19^{b}	11.83 ± 1.94^{a}	7.20 ± 0.49^{ab}	28.83 ± 2.50^{b}
80T + 20B	5.67 ± 0.92^{c}	12.00 ± 0.93^{a}	10.80 ± 1.83^{a}	26.67 ± 2.75^{b}
60T + 40B	4.17 ± 0.87^{c}	8.50 ± 1.33^{a}	10.67 ± 0.91^{a}	23.33 ± 2.32^{b}
50T + 50B	14.00 ± 0.71^{a}	9.33 ± 1.20^{a}	10.17 ± 1.05^{a}	34.50±2.31^{a}
40T + 60B	5.67 ± 0.84^{c}	9.80 ± 1.50^{a}	9.00 ± 1.22^{ab}	21.33 ± 3.20^{b}
20T + 80B	15.67 ± 1.43^{a}	13.00 ± 2.18^{a}	11.34 ± 1.76^{a}	40.00 ± 4.07^{a}
0T + 100B	9.67 ± 0.67^{b}	9.40 ± 1.36^{a}	5.17 ± 0.79^{b}	22.67±2.27^{a}
F	17.06	0.97	3.32	1.45
P	< 0.0001	0.4619	0.0121	0.2253

* T and B indicate *Tetranychus urticae* and *Bemisia tabaci* and percentage of 100, 80, 60, 50, 40, 20 and 0 corresponded to 150, 120, 90, 75, 60, 30 and 0 preys, respectively.
** Different letters in a same column revealed significant differences ($P < 0.05$, SNK).

DISCUSSION

In most greenhouses, populations of spider mites and whiteflies are simultaneously activated and cause economic damage to agricultural productions (Khanjani 2013). However, in view point of economic concerns, most agricultural producers prefer to manage such destructive populations with same strategies. Accordingly, a chemical pesticide such as Spiromesifen which has both insecticidal and acaricidal properties is so appropriate. Alam *et al*. (2014) revealed that this chemical has desirable toxicity against spider mites and whiteflies. Furthermore, they also reported that Spiromesifen was very safe to natural enemies like predatory coccinellid *Stethorus* sp. and predatory mite *Amblyseius* sp. Efficiency of Spiromesifen for combating populations of *T. urticae* was also noticed by Marcic *et al*. (2010).

Our findings revealed that recommended concentration of Spiromesifen has no detectable effects on mortality of adult predators. In fact, female predators exhibit a similar mortality pattern when feeding on different ratios of mixed prey and the results obtained showed that observed mortality has no dependency on application of chemical treatment. A review of literature revealed that integration of predatory mites and chemical pesticides was one of the most interesting objectives in recent years (Ditillo *et al*. 2016; Fernandez *et al*. 2017). Alinejad *et al*. (2016) demonstrated that understanding impacts of Spirodiclofen on biological performance of *A. swirskii* is crucial for successful implementation of integrated pest management programs. In another study, Ganjisaffar and Perring (2017) revealed that Hexythiazox has no negative effects on biological performance of *Galendromus flumenis* (Chant). These observations revealed that simultaneous application of natural enemies and chemical pesticides could be candidates as reliable options for management programs of phytophagous pests under greenhouse conditions. However, as the first step, safety of selected pesticides to natural enemies should be carefully investigated.

Our results obviously revealed that increasing the number of both preys in experimental arena significantly increases consumption rate of predatory mite *A. swirskii*. However, regression analysis showed that in the case of *T. urticae* this linear relationship was more intense. This evidence showed higher tendency of *A. swirskii* to feed on spider mites than whiteflies. The present finding is well corroborated with the earlier study by Heydari *et al*. (2016) which reported preference of *A. swirskii* for *T. urticae* than *B. tabaci*. However, in the 3rd day, linear relationship between initial number of *B. tabaci* and mean number of individuals eaten by *A. swirskii* was disrupted and predatory mite could not linearly response to population increase of this pest. A possible reason for this observation is higher toxicity of Spiromesifen to *B. tabaci*. Recommended concentration of

Spiromesifen for *T. tabaci* and *T. urticae* is 400 and 500 ml/ha (Nauen *et al*. 2005), respectively, and these values revealed higher toxicity of this chemical to *T. tabaci*. In our experiments, intermediate concentration (450 ml/ha) was tested and regarding the higher sensitivity of *B. tabaci* to Spiromesifen, it was expected to observe more negative effects on *B. tabaci* than *T. urticae*. Accordingly, whiteflies facedmore infection and this issue adversely affects consumption of *A. swirskii* on this pest. Another reason is higher mobility of *T. urticae* than *B. tabaci*. Xiao and Fadamiro (2010) stated that *A. swirskii* has higher preference to feed on mobile stages of *T. urticae*. In addition, this property allows *T. urticae* to escape from Spiromesifen droplets. However, since the immature stages of *T. tabaci* have lower mobility than *T. urticae*, Spiromesifen could have higher effects on its population.

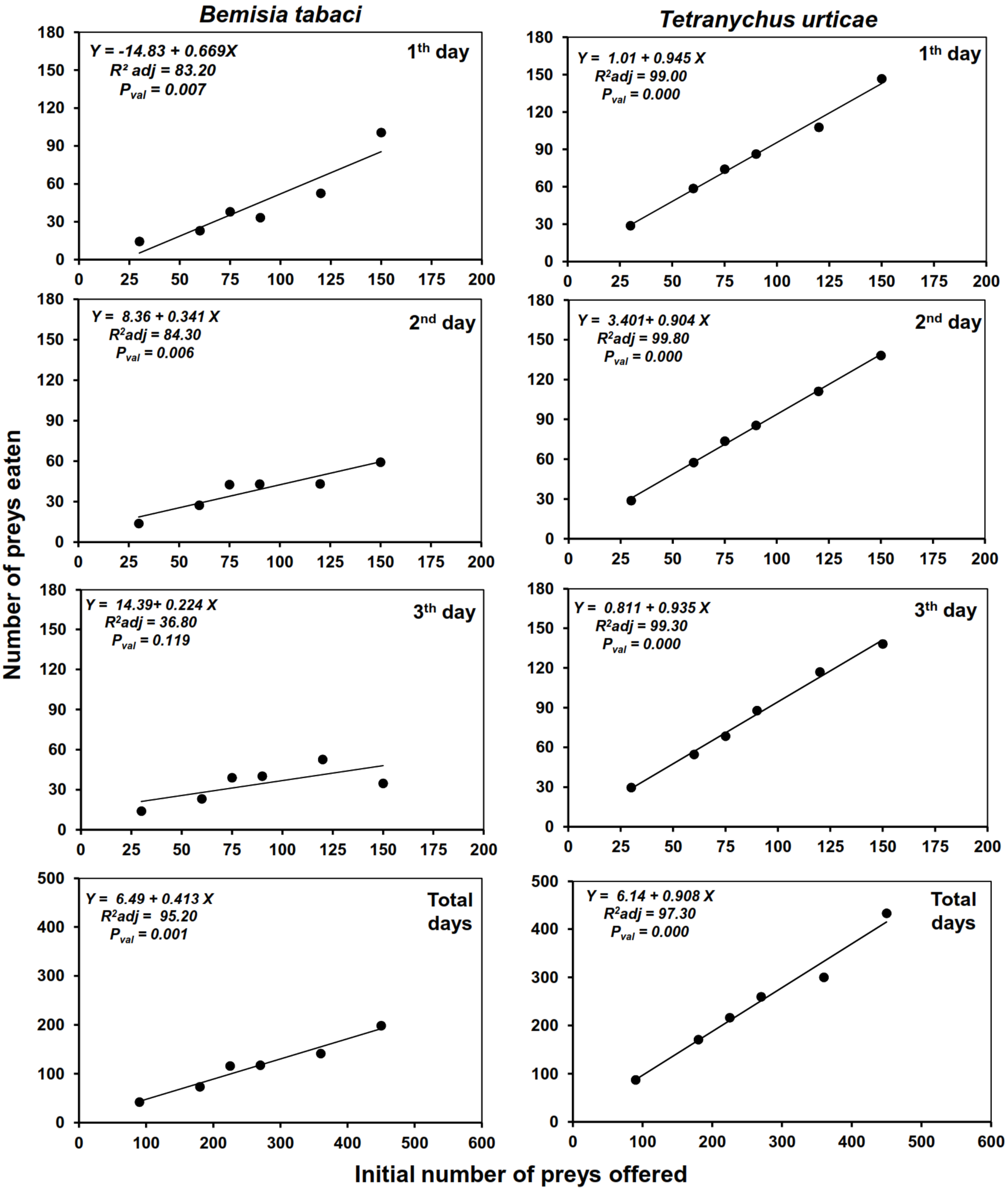

Figure 1. Linear relation between initial number of *Bemisia tabaci* (left)/ *Tetranychus urticae* (right) treated with recommended concentration of Spiromesifen and number of preys eaten by predatory mite *Amblyseius swirskii.*

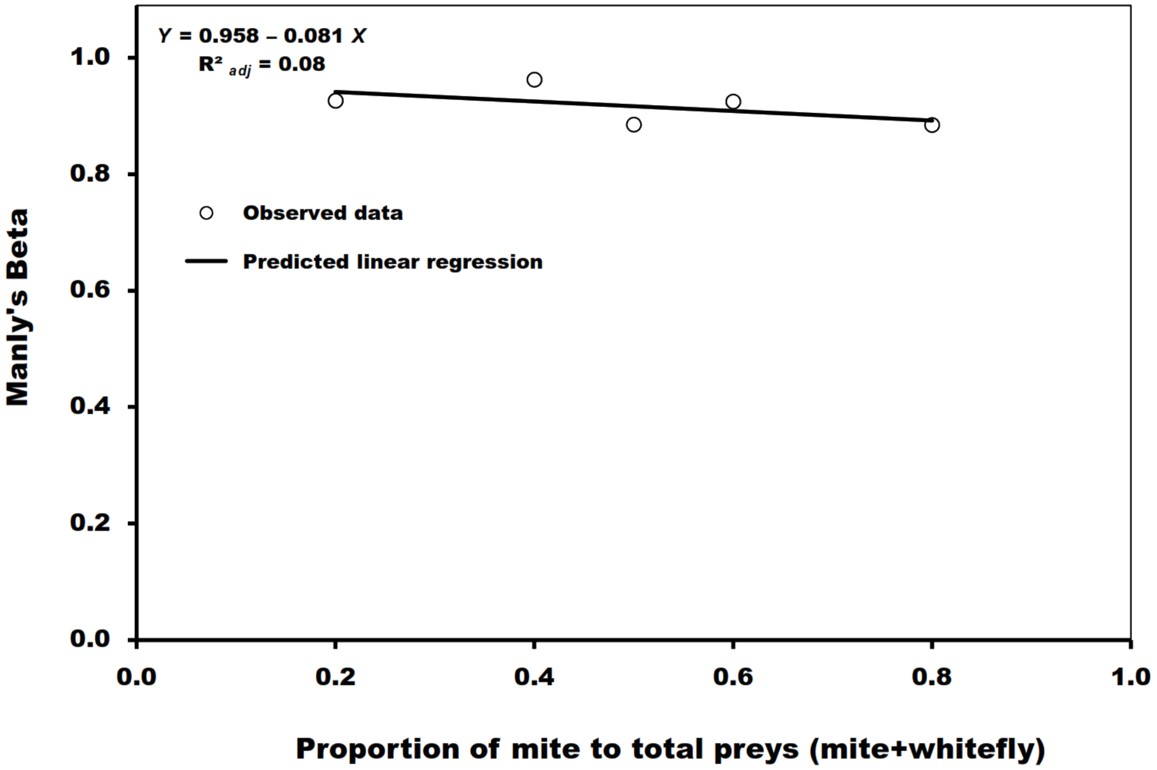

Figure 2. Fitted regression equation between the proportion of consumed mite to total preys and preference index (*β*) of *Amblyseius swirskii*.

These results revealed that *A. swirskii* has no switching behavior. The same results were reported by Heydari *et al*. (2016). In other words, our findings revealed that Spiromesifen has no significant effects on this behavioral character and increasing ratio of non-preferred prey (*B. tabaci*) in experimental arenas did not alter predation preference of *A. swirskii*. Xiao and Fadamiro (2010) investigated this behavior in three phytoseiid species including *Phytoseiulus persimilis* Athias-Henriot, *Galendromus occidentalis* (Nessbitt) and *Neoseiulus californicus* (McGregor). Their results revealed that *P. persimilis* has no switching but this behavior was reported for *N. californicus* and *G. occidentalis*. In another study, switching behavior was reported for some phytoseiid predators (Blackwood *et al*. 2001). However, switching behavior enables general predators to survive in conditions with low density of their preferred preys. Furthermore, having this behavior is much favorable for general predators to regulate population density of co-existence pests in same ecosystem (Murdoch and Marks 1973).

In conclusion, our findings revealed that general predator *A. swirskii* could attack both *T. urticae* and *B. tabaci*. However, this predatory mite has more preference to *T. urticae* and it is so important to consider this crucial point for appropriate usage of this predator. Furthermore, because of no detectable effects of Spiromesifen on biological and behavioral attributes of *A. swirskii*, simultaneous application of these combating options could be considered as a reliable tool for implementation of integrated management programs under greenhouse conditions.

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چگونگی تأثیر اسپیرومسیفن روی برخی پارامترهای زیستی و رفتار ترجیح غذایی کنهٔ شکارگر ***Amblyseius swiriskii*** (Acari: Phytoseiidae) با تغذیه از نسبت‌های مختلف طعمهٔ مخلوط

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چکیده

کنهٔ تارتن دولکه‌ای، *Tetranychus urticae* Koch (Acari: Tetranychidae) و سفیدبالک پنبه، *Bemisia tabaci* (Gennadius) (Hem.: Aleyrodidae)، از جمله مهم‌ترین آفات گلخانه‌ها هستند. اسپیرومسیفن (ابرون®) از جمله آفت‌کش‌های شیمیایی است که با داشتن خاصیت کشندگی روی هر دو آفت مذکور به‌صورت گسترده‌ای مورد استفاده قرار می‌گیرد. در پژوهش حاضر، اثرهای غلظت توصیه شدهٔ این آفت‌کش روی برخی پارامترهای زیستی و رفتاری کنهٔ شکارگر *Amblyseius swirskii* Athias-Henriot (Acari: Phytoseiidae) با تغذیه از نسبت‌های مختلف این آفات مورد مطالعه قرار گرفت. نسبت‌های مختلف مورد مطالعه از این دو آفت شامل ۱ (۱۵۰ عدد مراحل نابالغ کنهٔ تارتن دولکه‌ای + ۰ عدد مراحل نابالغ سفیدبالک پنبه)، ۲ (۱۲۰ عدد کنه + ۳۰ عدد سفیدبالک)، ۳ (۹۰ عدد کنه + ۶۰ عدد سفیدبالک)، ۴ (۷۵ عدد کنه + ۷۵ عدد سفیدبالک)، ۵ (۶۰ عدد کنه + ۹۰ عدد سفیدبالک)، ۶ (۳۰ عدد کنه + ۱۲۰ عدد سفیدبالک) و ۷ (۰ عدد کنه +۱۵۰ عدد سفیدبالک) بود. درصد مرگ و میر ماده‌های بالغ کنهٔ شکارگر *A. swiriskii* تحت تأثیر تغذیه از درصدهای مختلف طعمه قرار نگرفت. افزایش نسبت کنهٔ تارتن و سفیدبالک در تیمارهای مختلف مورد مطالعه، افزایش میزان تغذیهٔ کنهٔ شکارگر را به دنبال داشت. با وجود این، رابطهٔ خطی میان تعداد طعمهٔ ارایه شده و تعداد طعمهٔ مصرف شده توسط کنهٔ شکارگر *A. swirskii* در مورد کنهٔ تارتن دولکه‌ای از نظر آماری معنی‌داری بیش‌تری داشت. باروری کنهٔ شکارگر نسبت به تغذیه از نسبت‌های مختلف طعمه روند مشخصی نشان نداد. افزون بر این، رفتار تغییر ترجیح غذایی (Switching) در کنهٔ شکارگر *A. swirskii* مشاهده نشد. یافته‌های پژوهش حاضر می‌تواند در افزایش کارایی بیولوژیک کنهٔ شکارگر *A. swirskii* در برنامه‌های مدیریت تلفیقی آفات مختلف مورد استفاده قرار گیرد.

واژگان کلیدی: مهار زیستی؛ مهار شیمیایی؛ کنه‌های شکارگر؛ کنه‌های تارتن؛ سفیدبالک‌ها.

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